3. Biggs–West Gridley Water District

This section of the Feather River Regional AWMP contains plan components specific to Biggs–West Gridley Water District (BWGWD).

3.1 Contents

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3.2 Introduction

This 2015 Agricultural Water Management Plan (AWMP) has been prepared in accordance with the requirements of the Water Conservation Act of 2009 (SBx7-7) and Executive Order B-29-15, issued April 1, 2015. As an agricultural water supplier in Butte County, BWGWD works to ensure the long term reliability, quality, and affordability of local surface water and groundwater supplies. Development of this AWMP represents a substantial effort by BWGWD to evaluate its water management activities, including the development of detailed water balances spanning the period from 1999 to 2014. Additionally, BWGWD has evaluated the implementation of the full range of Efficient Water Management Practices (EWMPs) described in SBx7-7 with respect to its water management objectives and activities and has evaluated resulting Water Use Efficiency (WUE) improvements.

The BWGWD AWMP includes the following:

- Cross-reference of plan components to requirements of SBx7-7 and Executive Order B-29-15,
- Description of the process to prepare and adopt the plan,
- Background and description of the service area,
- Inventory of water supplies,
- Water balance analysis of historical water use,
- Evaluation of potential climate change impacts and adaptation strategies,
- Evaluation of water management activities and opportunities related to EWMPs and WUE improvements

BWGWD has participated in several local, regional, and statewide water management activities, as described throughout this AWMP. BWGWD previously prepared an AWMP in 2014.

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3.3 Cross-Reference to Requirements of SBx7-7

Table 3.1 provides a cross-reference of the requirements of the California Water Code (CWC) to the AWMP sections contained herein.

Table 3.1. Cross-Reference of Relevant Sections of the California Water Code and Executive Order B-29-15 to BWGWD 2015 AWMP.

California Water Code, Division 6, Part 2.55. Sustainable Water Use and Demand Reduction

Chapter 4. Agricultural Water Suppliers				
Division	Subdivision	Paragraph	Code Language	Applicable AWMP Section(s)
10608.48	(a)		On or before July 31, 2012, an agricultural water supplier shall implement efficient water management practices pursuant to subdivisions (b) and (c).	**II.3.9.1**
	(b)		Agricultural water suppliers shall implement all of the following critical efficient management practices:	(see below)
		(1)	Measure the volume of water delivered to customers with sufficient accuracy to comply with subdivision (a) of Section 531.10 and to implement paragraph (2)	**II.3.9.1, II.3.5.7, II.3.10.3**
		(2)	Adopt a pricing structure for water customers based at least in part on quantity delivered.	**II.3.9.1, II.3.5.8, II.3.10.3**
	(c)		Agricultural water suppliers shall implement additional efficient management practices, including, but not limited to, practices to accomplish all of the following, if the measures are locally cost effective and technically feasible:	(see below)
		(1)	Facilitate alternative land use for lands with exceptionally high water duties or whose irrigation contributes to significant problems, including drainage.	**II.3.9.1**
		(2)	Facilitate use of available recycled water that otherwise would not be used beneficially, meets all health and safety criteria, and does not harm crops or soils.	**II.3.9.1**
		(3)	Facilitate the financing of capital improvements for on-farm irrigation systems.	**II.3.9.1**
		(4)	Implement an incentive pricing structure that promotes one or more of the following goals: (A) More efficient water use at the farm level. (B) Conjunctive use of groundwater. (C) Appropriate increase of groundwater recharge. (D) Reduction in problem drainage. (E) Improved management of environmental resources. (F) Effective management of all water sources throughout the year by adjusting seasonal pricing structures based on current conditions.	**II.3.9.1**
		(5)	Expand line or pipe distribution systems, and construct regulatory reservoirs to increase distribution system flexibility and capacity, decrease maintenance, and reduce seepage.	**II.3.9.1**
		(6)	Increase flexibility in water ordering by, and delivery to, water customers within operational limits.	**II.3.9.1**
		(7)	Construct and operate supplier spill and tailwater recovery systems.	**II.3.9.1**
		(8)	Increase planned conjunctive use of surface water and groundwater within the supplier service area.	**II.3.9.1**
		(9)	Automate canal control structures.	**II.3.9.1**
		(10)	Facilitate or promote customer pump testing and evaluation.	**II.3.9.1**
		(11)	Designate a water conservation coordinator who will develop and implement the water management plan and prepare progress reports.	**II.3.9.1**
		(12)	Provide for the availability of water management services to water users. These services may include, but are not limited to, all of the following: (A) On-farm irrigation and drainage system evaluations. (B) Normal year and real-time irrigation scheduling and crop evapotranspiration information. (C) Surface water, groundwater, and drainage water quantity and quality data. (D) Agricultural water management educational programs and materials for farmers, staff, and the public.	**II.3.9.1**
		(13)	Evaluate the policies of agencies that provide the supplier with water to identify the potential for institutional changes to allow more flexible water deliveries and storage.	**II.3.9.1**
		(14)	Evaluate and improve the efficiencies of the supplier's pumps.	**II.3.9.1**
10608.48	(d)		Agricultural water suppliers shall include in the agricultural water management plans required pursuant to Part 2.8 (commencing with Section 10800) a report on which efficient water management practices have been implemented and are planned to be implemented, an estimate of the water use efficiency improvements that have occurred since the last report, and an estimate of the water use efficiency improvements estimated to occur five and 10 years in the future. If an agricultural water supplier determines that an efficient water management practice is not locally cost effective or technically feasible, the supplier shall submit information documenting that determination.	**II.3.9.1, II.3.9.2**

California Water Code, Division 6, Part 2.8. Agricultural Water Management Planning

Chapter 3. Agricultural Water Management Plans
Article 1. General Provisions

Division	Subdivision	Paragraph	Code Language	Applicable AWMP Section(s)
10820	(a)		An agricultural water supplier shall prepare and adopt an agricultural water management plan in the manner set forth in this chapter on or before December 31, 2012, and shall update that plan on December 31, 2015, and on or before December 31 every five years thereafter.	**II.3.2, II.3.4, II.3.10.1**
10821	(a)		An agricultural water supplier required to prepare a plan pursuant to this part shall notify each city or county within which the supplier provides water supplies that the agricultural water supplier will be preparing the plan or reviewing the plan and considering amendments or changes to the plan. The agricultural water supplier may consult with, and obtain comments from, each city or county that receives notice pursuant to this subdivision.	**II.3.10.1**
	(b)		The amendments to, or changes in, the plan shall be adopted and submitted in the manner set forth in Article 3 (commencing with Section 10840).	**II.3.10.1**
Article 2. Contents of Plans				
Division	Subdivision	Paragraph	Code Language	Applicable AWMP Section(s)
10826			An agricultural water management plan shall be adopted in accordance with this chapter. The plan shall do all of the following:	(see below)
	(a)		Describe the agricultural water supplier and the service area, including all of the following:	(see below)
		(1)	Size of the service area.	**II.3.5.2**
		(2)	Location of the service area and its water management facilities.	**II.3.5.3**
		(3)	Terrain and soils.	**II.3.5.4**
		(4)	Climate.	**II.3.5.5**
		(5)	Operating rules and regulations.	**II.3.5.6**
		(6)	Water delivery measurements or calculations.	**II.3.5.7**
		(7)	Water rate schedules and billing.	**II.3.5.8**
		(8)	Water shortage allocation policies.	**II.3.5.9**
10826	(b)		Describe the quantity and quality of water resources of the agricultural water supplier, including all of the following:	(see below)
		(1)	Surface water supply.	**II.3.6.2**
		(2)	Groundwater supply.	**II.3.6.3**
		(3)	Other water supplies.	**II.3.6.4**
		(4)	Source water quality monitoring practices.	**II.3.6.5**
		(5)	Water uses within the agricultural water supplier's service area, including all of the following: (A) Agricultural. (B) Environmental. (C) Recreational. (D) Municipal and industrial. (E) Groundwater recharge. (F) Transfers and exchanges. (G) Other water uses.	**II.3.7.3**
		(6)	Drainage from the water supplier's service area.	**II.3.7.4**
10826	(b)	(7)	Water accounting, including all of the following: (A) Quantifying the water supplier's water supplies. (B) Tabulating water uses. (C) Overall water budget.	**II.3.7.5**
		(8)	Water supply reliability.	**II.3.5.9**
	(c)		Include an analysis, based on available information, of the effect of climate change on future water supplies.	**II.3.8**
	(d)		Describe previous water management activities.	**II.3.2, II.3.5, II.3.6, II.3.9**
	(e)		Include in the plan the water use efficiency information required pursuant to Section 10608.48.	**II.3.9.2**
Article 3. Adoption and Implementation of Plans				
Division	Subdivision	Paragraph	Code Language	Applicable AWMP Section(s)
10841			Prior to adopting a plan, the agricultural water supplier shall make the proposed plan available for public inspection, and shall hold a public hearing on the plan. Prior to the hearing, notice of the time and place of hearing shall be published within the jurisdiction of the publicly owned agricultural water supplier pursuant to Section 6066 of the Government Code. A privately owned agricultural water supplier shall provide an equivalent notice within its service area and shall provide a reasonably equivalent opportunity that would otherwise be afforded through a public hearing process for interested parties to provide input on the plan. After the hearing, the plan shall be adopted as prepared or as modified during or after the hearing.	**II.3.10.1**

10842			An agricultural water supplier shall implement the plan adopted pursuant to this chapter in accordance with the schedule set forth in its plan, as determined by the governing body of the agricultural water supplier.	**II.3.9**
10843	(a)		An agricultural water supplier shall submit to the entities identified in subdivision (b) a copy of its plan no later than 30 days after the adoption of the plan. Copies of amendments or changes to the plans shall be submitted to the entities identified in subdivision (b) within 30 days after the adoption of the amendments or changes.	**II.3.10.1**
	(b)		An agricultural water supplier shall submit a copy of its plan and amendments or changes to the plan to each of the following entities:	(see below)
		(1)	The department.	**II.3.10.1**
		(2)	Any city, county, or city and county within which the agricultural water supplier provides water supplies.	**II.3.10.1**
		(3)	Any groundwater management entity within which jurisdiction the agricultural water supplier extracts or provides water supplies.	**II.3.10.1**
		(4)	Any urban water supplier within which jurisdiction the agricultural water supplier provides water supplies.	**II.3.10.1**
		(5)	Any city or county library within which jurisdiction the agricultural water supplier provides water supplies.	**II.3.10.1**
		(6)	The California State Library.	**II.3.10.1**
		(7)	Any local agency formation commission serving a county within which the agricultural water supplier provides water supplies.	**II.3.10.1**
10844	(a)		Not later than 30 days after the date of adopting its plan, the agricultural water supplier shall make the plan available for public review on the agricultural water supplier's Internet Web site.	**II.3.10.1**
	(b)		An agricultural water supplier that does not have an Internet Web site shall submit to the department, not later than 30 days after the date of adopting its plan, a copy of the adopted plan in an electronic format. The department shall make the plan available for public review on the department's Internet Web site.	**Not Applicable**

Governor Edmund G. Brown Executive Order B-29-15

Item 12. Agricultural Water Suppliers (more than 25,000 acres)		
Item	Order Language	Applicable AWMP Section(s)
12	Agricultural water suppliers that supply water to more than 25,000 acres shall include in their required 2015 Agricultural Water Management Plans a detailed drought management plan that describes the actions and measures the supplier will take to manage water demand during drought. The Department shall require those plans to include quantification of water supplies and demands for 2013, 2014, and 2015 to the extent data is available. The Department will provide technical assistance to water suppliers in preparing the plans.	**II.3.5.9, II.3.7, II.3.10.5**

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3.4 Plan Preparation and Adoption

3.4.1 Regulatory Compliance

As described previously, this AWMP has been prepared in accordance with SBx7-7 and the CWC and with Executive Order B-29-15.

3.4.2 Public Participation and Adoption

Requirements of the CWC and Government Code 6066 related to public review and adoption of AWMPs include the following:

- CWC §10821(a) – An agricultural water supplier required to prepare an AWMP must notify each city or county within which it supplies water that the AWMP will be prepared.
- CWC §10841 – Prior to adopting an AWMP, agricultural water suppliers must make the plan available for public inspection and hold a public hearing. Prior to the hearing, notice of the time and place must be published within the supplier's jurisdiction pursuant to Section 6066 of the Government Code.
- Government Code §6066 – Publication of notice shall be once a week for two successive weeks in a newspaper of general circulation.
- CWC §10843 – A copy of the adopted AWMP must be provided to the following entities within 30 days of the date of adoption:
    - The California Department of Water Resources (DWR),
    - Any city or county within which the supplier provides water,
    - Any groundwater management entity within which the supplier extracts or supplies water,
    - Any urban water supplier within which the supplier provides water,
    - Any city or county library within which the supplier provides water,
    - The California State Library, and
    - Any local agency formation commission serving a county within which the supplier provides water.
- CWC §10844 – Within 30 days of the date of adoption, the supplier must make the AWMP available on its website (if applicable), or submit an electronic copy to be made available by DWR.

The public participation and adoption process for BWGWD is documented in Section 3.10.1.

3.4.3 Regional Coordination

This AWMP was originally developed as part of the Feather River Regional AWMP (FRRAWMP), which was funded by a Proposition 204 grant awarded by DWR to the Northern California Water Association (NCWA). Development of the plan included coordination among the following Feather River water suppliers and water management entities:

- Joint Water Districts

  - Biggs – West Gridley Water District (BWGWD)
  - Butte Water District (BWD)
  - Richvale Irrigation District (RID)
  - Sutter Extension Water District (SEWD)
- Western Canal Water District (WCWD)
- Lower Feather Water Users
  - Feather Water District (FWD)
  - Garden Highway Mutual Water Company (GHMWC)
  - Plumas Mutual Water Company (PMWC)
  - Tudor Mutual Water Company (TMWC)
  - Sutter Butte – Butte Slough Water Users Association

Additionally, development of the FRRAWMP included consultation with representatives of the Butte County Department of Water and Resource Conservation, the California Department of Fish and Wildlife, the U.S. Fish and Wildlife Service, and the DWR Northern Region.

The preparation of a regional AWMP for the Feather River region provides the opportunity to evaluate water management within the region as a whole and exposes interdependencies between agricultural water suppliers and other water uses, including other agriculture in the region and terrestrial and aquatic ecosystems. Water use in the region can be described as "cascading" where water diverted and applied on an individual farm or within an individual supplier service area that is not consumed to produce crops or habitat vegetation moves down through the system and remains available for other beneficial uses.

This 2015 update to BWGWD's AWMP has been funded solely by BWGWD and builds upon and updates the 2014 FRRAWMP.

3.5 Background and Description of Service Area

3.5.1 History and Organization

BWGWD is a California Water District responsible for providing irrigation water to agricultural water users within its service area. BWGWD was formed by a vote of landowners on September 24, 1942. Petitions for the formation of the District had been signed by landowners and presented at the Butte County Board of Supervisors chamber in connection with a hearing earlier that year. Following formation, an election was held on December 21, 1942 to determine whether or not to issue bonds to provide revenue for the beginning of operations. More than half of the eligible voters participated in the election, unanimously voting in favor of issuing the bonds, and the district purchased 28% of the Sutter Butte Canal Company's (SBCC) properties and pre-1914 water rights. The district's service area and distribution system have been further expanded over the years (BWGWD 1973, McGee 1980), and it currently encompasses 34,785 acres of land. In 1957 BWGWD, Richvale Irrigation District (RID), Butte Water District (BWD), and Sutter Extension Water District (SEWD) organized to form the Joint Water Districts Board (Joint Districts) to coordinate their efforts in managing the SBCC distribution system which they all share a portion of. In 1969, the

Joint Districts entered into a settlement agreement with the State allowing for the diversion of up to 555,000 af from the Feather River at the Thermalito Afterbay following its construction and the construction of Lake Oroville as part of the State Water Project.

Since its inception, a majority of the land in the district has been in rice production due to the dominance of heavy clay soils, favorable climate, and availability of water for irrigation. Including crops other than rice, it has served an average of 26,600 irrigable acres (includes fallowed acres) between 1999 and 2014[1], as well as approximately 3,700 acres of the CDFW Gray Lodge Wildlife Area and 1,000 acres of the USFWS Butte Sink Wildlife Management Area.

BWGWD is entitled to approximately 161,000 af of the Joint Districts allowed diversions from the Feather River between April 1 and October 31 of each year under the 1969 agreement with the State, which is subject to reduction under certain conditions, as described below. The district is represented by a board of directors made up of five members. Each director is elected for a four-year term by landowners within the district. The board of directors elect a board president to run the meetings, a vice-president to serve if the board president is unavailable, and a board secretary and treasurer.

The general manager is principal administrative officer of the district. Currently, there are seven full-time district employees. They include the general manager, office assistant, and five system operators. An accountant and attorney also work for the district as needed. The staff additionally run fall and winter water deliveries for rice decomposition and waterfowl and shorebird habitat beginning in November and continuing through mid-January, and perform winter maintenance activities outside of the irrigation season. An organizational chart of the district is provided in Figure 3.1.

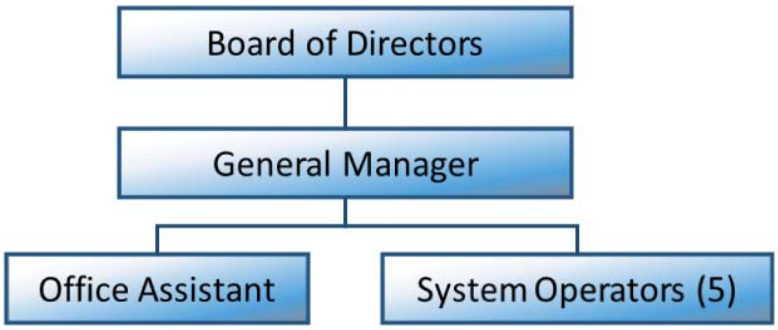

Figure 3.1. Organizational Chart.

3.5.2 Size and Location of Service Area

BWGWD is located in the Sacramento Valley, north of the Sutter Buttes. The cities of Biggs and Gridley lie along its eastern boundary, as well as Butte Water District (Figure 3.2). The district is bounded on the north by the Cherokee Canal and the boundary with RID. Butte Creek and the Butte

[1] Based on DWR land and water use surveys, agricultural commissioner crop reports, and annual reports of the Joint Districts Board.

Slough lie to the west, and Snake Creek originates at the district's southern boundary and carries water south around the east side of the Sutter Buttes. BWGWD's southern boundary intersects the Gray Lodge Wildlife Area (Gray Lodge), to which the district delivers water as a district customer and as provided by the U.S Bureau of Reclamation (USBR) under the Central Valley Improvement Act (CVPIA). The district's service area is approximately 35,000 acres, of which approximately 25,400 crop acres were irrigated, on average, between 1999 and 2014. For that time period, rice production constituted approximately 85% of the irrigated acreage. The remaining cropped area includes a combination of orchards, pasture, and row crops (14%). Approximately 1,200 irrigable acres, on average, were idled during this period.

The location of BWGWD's service area relative to the Sacramento Valley as a whole and the Feather River Region is shown in Volume I, Section 2 of this AWMP.

3.5.3 Distribution and Drainage System

The BWGWD distribution system is shown in Figure 3.2. The figure shows the service area and surrounding areas, irrigation and drainage facilities, natural waterways, and points of surface water inflow to and outflow from the district.

The distribution system is an open, gravity flow system operated via upstream level control. Daily diversions are adjusted through coordination with the Joint Districts Manager, who, in turn, coordinates releases with DWR operators of Thermalito Afterbay, the source of the district's diversions. Water level fluctuations in the afterbay result in fluctuations in deliveries to BWGWD and the other joint districts which are propagated through the districts' distribution systems to varying degrees. BWGWD and RID are subject to a relatively large portion of the fluctuations during much of the irrigation season due to capacity flows in the Sutter Butte Canal through the Looney Gates. Flow fluctuations and potential projects to improve operation of the Joint District system are discussed in greater detail in Volume II, Section 10.1.

The primary diversion of water into BWGWD is from the Biggs Extension Canal, which branches from the Sutter-Butte Canal and serves both BWGWD and RID. There exist turnouts to individual fields and private lateral headings along the extension canal upstream of the BWGWD Main Canal heading that are served by the joint districts manager. Control of water by BWGWD operators begins at the Main Canal Heading (capacity of 700 cfs, also known as the Belding). At this location is also the heading of the Branch A Lateral (capacity of 25 cfs, also known as the Dietzler). The Main Canal generally runs from north to south and is approximately 10 miles in length; the Branch A Lateral is approximately 2 miles long.

Water is conveyed by the canal and lateral system through a series of control structures used to maintain desired upstream water levels, subject to certain physical and operational constraints. This enables gravity delivery through turnouts where possible but requires pumping of water in some locations. At the ends of the laterals are safety spills or "safeties," which are used to convey operational spillage into drains and sloughs and to deliver water to downstream water users in some cases.

The BWGWD distribution system consists of the main canal, branches, and laterals. For classification purposes the main canal conveys a majority of the water diverted through the district, branches are laterals that leads to at least one other lateral (as well as turnouts), and laterals lead only to field turnouts. The BWGWD distribution system is made up of the Main Canal, 5 branches, and 22 laterals. The total length of these canals is about 56 miles. The Main Canal and two branches deliver water to Gray Lodge Wildlife Area at the tail end of distribution system.

There additionally exist individual turnouts and private lateral headings serving BWGWD customers located directly on the Sutter-Butte Canal, downstream of the heading of the Biggs Extension Canal. Farther downstream there is also delivery from a BWD canal known as Lateral 8, which originates from the Sutter-Butte Canal. These deliveries to BWGWD customers are coordinated with BWD.

For the period 1999 to 2014, BWGWD diverted between approximately 153,000 and 224,000 af into the Main Canal, between approximately 3,000 and 6,000 af into Branch A, between approximately 6,000 and 9,000 af into Lateral 8, and between approximately 8,000 and 25,000 af into miscellaneous deliveries from the Sutter-Butte Canal and from the Biggs Extension before it reaches the Main Canal[2]. The annual totals for all diversions for the period range from 210,000 af in 2003 to 255,000 af in 2004. Annual diversions depend upon a combination of factors, including demands from district customers, deliveries to Gray Lodge Wildlife Area and out of district landowners, and infrequent reductions based on the Joint District's settlement agreement with the State[3]. Annual diversions include diversions accounted against BWGWD's allotment during the irrigation season, diversions during the non-irrigation season (not accounted against BWGWD's allotment), and diversions of water during the irrigation season purchased from other Joint Districts in some years (accounted for against the provider's allotment). Additionally, as mentioned previously, BWGWD wheels water to Gray Lodge provided by USBR under the CVPIA.

The Main Canal includes 8 primary control structures, many of which will be retrofitted or replaced as part of the Gray Lodge Wildlife Area Water Supply Project[4], which is being funded through the CVPIA to increase delivery capacity and reliability along the Main Canal and laterals to the Rising River, Cassaday, and Schwind delivery points to Gray Lodge. There exist several control structures at lateral headings and along laterals that will not be replaced through the project. Deliveries are made to fields at approximately 390 individual turnouts.

The district is divided into three operational divisions. The divisions operate under the supervision of the general manager. Within divisions, actual field operations are executed by three primary system operators and one relief operator. The remaining operator (there are five in total) serves

[2] Expressed on a water year basis (October – September) based on reports of the Joint Districts Board. Total annual diversions may exceed the district's 161,000 af entitlement in part due to non-allotted winter diversions for wildlife habitat and rice straw decomposition.
[3] Historical, the district's supply has been reduced in four years: 1977, 1991, 1992, and 2015.
[4] Two structures, Banion Check and Fields Flume, were replaced during the winter of 2014. Seven structures, Ashley Headgates, Garcia Flume, Garcia Check, North Check, Traynor Heading, Division 2 Headgates, and Nugent Flume, were replaced during the winter of 2015.

primarily as a maintenance worker but can be called upon to provide relief to the other operators under certain conditions. Division sizes average approximately 8,800 acres. The divisions have been delineated to achieve uniform division of workloads among operators.

The distribution and drainage systems within BWGWD are highly integrated. For example, BWGWD operates six recycle pump stations to lift water out of drains back into the distribution system for reuse. Canals and laterals primarily purposed for the delivery of water also collect and redistribute drainwater for irrigation in these instances. Similarly, drains primarily purposed to convey runoff from irrigation and precipitation and to provide shallow groundwater relief also serve as channels to convey water for irrigation in some cases. Water is often delivered into drains at safety spills and used downstream for irrigation. In nearly all of these cases, growers use private pumps to lift water onto their fields for irrigation.

Drainage in BWGWD occurs through both naturally occurring waterways and man-made drains. Reclamation District 833 (RD833) operates and maintains the drains in the northern portion of the district that drain to the southwest to Butte Creek, and Reclamation District 2054 (RD2054) operates and maintains the drains in the southeastern portion of BWGWD that drain south around the east side of the Sutter Buttes. Drainwater flows to the southwest to Butte Creek through Hamilton Drain, Brooks Drain, and Meyers Drain. Snake Creek, which originates at BWGWD's southern boundary, is a natural waterway that collects surface drainage from manmade drains and conveys it around the eastern side of the Buttes into BWD.

There are approximately 25 miles of primary drains within BWGWD. It is estimated that there are in excess of 100 miles of secondary drains that carry water to primary drains. Excess system flows in the distribution system, if present, can be released from the system at approximately 40 safety spills or "safeties". Many of the safeties additionally serve as delivery points for the water users along drains and natural sloughs, which lie downgradient of the existing distribution system.

The irrigation and drainage system primarily consists of unlined ditches, although pipelines carry water through developed areas in the eastern portion of the District. Seepage losses from ditches are limited by clay soils with underlying impermeable layers and generally shallow groundwater conditions within a majority of BWGWD.

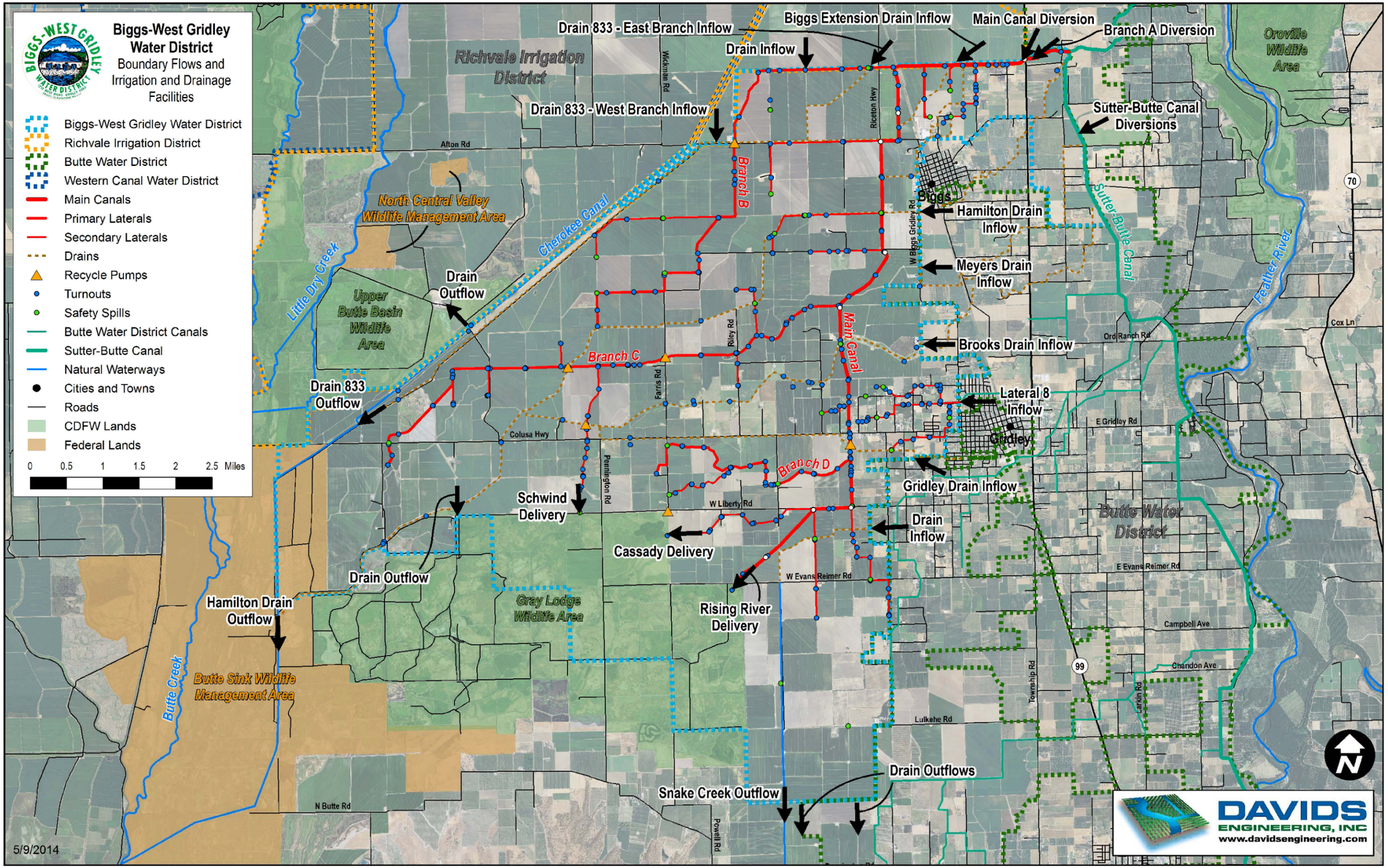

Figure 3.2. Boundary Flows and Irrigation and Drainage Facilities.

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The district's water delivery practices have evolved primarily to meet the irrigation and cultural practice needs of rice, the dominant crop; however, there are several laterals used to deliver water to orchards and other crops along the eastern boundary of the district. During periods of flood-up in the spring, water has historically been delivered on an arranged-demand basis, where growers place orders directly with system operators, and water deliveries are generally made in the sequence orders were received, subject to operational constraints. Once rice is established, continuous deliveries are made as needed to maintain rice pond levels (except when deliveries are ceased and water is held or drained to support chemical applications), with potential periodic adjustments to match crop evapotranspiration and deep percolation rates while limiting tailwater outflow. For additional detail describing water management objectives for rice production, see Volume I, Section 4 of this AWMP. For the orchards and other crops grown in the district, a combination of pressurized and surface irrigation methods are used, and delivery requests are filled on an arranged-demand basis. Orders are generally filled with 24-hours lead time, but are often filled with less lead time when operational constraints allow.

The irrigation season begins in April or May with flood up of the rice fields. Following flood up, diversions and deliveries remain relatively steady to maintain pond levels, with individual fields being drained for herbicide applications and re-flooded in some cases. Deliveries typically decrease in August and September in preparation for harvest. Fall and winter deliveries for rice straw decomposition begin in October and continue through mid-January. Winter flooding is integral to rice production in the Sacramento Valley and provides waterfowl and shorebird habitat. From the period of 1999 through 2014, diversions during the irrigation season (April through September) have been relatively consistent. Irrigation season diversions ranged between 114,000 and 192,000 af from 1999 to 2014 with an average of 163,000 af[5]. Minimum diversions occurred in 2014 and reflect a combination of increased use of district recycle pumps, reduced spillage by system operators, and idling of rice lands for transfer. Fall and winter diversions steadily increased between 1992 and 2001 and have remained relatively steady since that time. The increase is primarily a result of the Connelly-Areias-Chandler Rice Straw Burning Reduction Act of 1991, which phased out rice straw burning, except under special circumstances, between 1992 and 2001. Instead of burning, rice straw is now commonly decomposed via winter flooding between November and January, with the flooded fields providing important food and habitat for migratory waterfowl, shorebirds, and other species.

3.5.4 Terrain and Soils

BWGWD is located on the Sacramento Valley floor, and the topography within the district is generally flat. Land surface elevation varies from approximately 110 feet above mean sea level in the northeastern portion of the district to about 75 feet in the southeast and 60 feet in the southwest. Drainage generally flows to the south and around the Sutter Buttes either to the southwest around the western edge towards Butte Creek or to the southeast into Snake Creek around the eastern edge. The majority of drainage flows to the southwest through the Butte Sink.

[5] BWGWD has diverted more than its 161,000 af allotment in some years and purchased transfer water from BWD and SEWD. Additionally, BWGWD diverts and delivers CVPIA water provided by USBR, which is not accounted against the district's allotment.

The land falls to the southeast at approximately 0.7 feet per thousand feet (0.07 percent) to the southwest at approximately 0.8 feet per thousand feet (0.08 percent) with lesser slopes in the southern portion of the District as compared to the northern portion. As mentioned previously, drainage to the southwest flows through RD833 drains, and drainage to the southeast flows through RD2054 drains.

Soils within BWGWD are generally classified as clayey alluvium over cemented loamy alluvium. Eight soil map units, as defined by the Natural Resources Conservation Service (NRCS 2006a), comprise approximately 91 percent of the irrigated area. Characteristics of these map units are summarized in Table 3.2. For approximately 65 percent of the area, available water holding capacity exceeds five inches in the top five feet, and it is approximately four inches in the remaining area. The soils are poorly drained with typically very low saturated hydraulic conductivity. A restrictive, duripan layer exists generally throughout the district, typically at a depth of 20 to 60 inches; however sand lenses exist in some areas, allowing for preferential flow between the surface water and groundwater systems. Soils in the district are well suited for rice production.

Table 3.2. Characteristics of Dominant Soils.

Soil Map Unit	Percent of Area	Land-form(s)	Slope Range	Parent Material	Available Water Holding Capacity	Drainage	Saturated Hydraulic Conductivity Class	Restrictive Layer	Depth to Water Table	Typical Profile[1]	
Lofgren-Blavo Complex	25%	basin floors on valleys	0 to 1 percent	clayey alluvium over cemented loamy alluvium	5.3 to 6.7 inches in top 5 feet	poorly drained	very low	duripan at 20 to 60 inches	20 to 59 inches	0 - 44 inches:	clay
										44 - 47 inches:	clay loam
										47 - 62 inches:	cemented material
Esquon-Neerdobe Complex	23%	basin floors on valleys	0 to 1 percent	clayey alluvium over cemented loamy alluvium	5.8 to 8.9 inches in top five feet	poorly drained	very low	duripan at 20 to 60 inches	20 to 59 inches	0 - 46 inches:	clay
										46 - 56 inches:	silty clay
										56 - 67 inches:	cemented material
Gridley Taxadjunct Loam	13%	terraces on valleys	0 to 2 percent	loamy and clayey alluvium over cemented loamy alluvium	3.9 inches in top 5 feet	somewhat poorly drained	very low	duripan at 20 to 40 inches	15 to 20 inches	0 - 10 inches:	loam
										10 - 20 inches:	clay loam
										20 - 22 inches:	clay
										22 - 60 inches:	cemented material
Subaco Taxadjunct Loam	11%	basin floors on valleys	0 to 1 percent	clayey alluvium over cemented fine-silty alluvium over	5.3 inches in top 5 feet	poorly drained	very low	duripan at 20 to 40 inches	20 to 34 inches	0 - 8 inches:	clay
										8 - 29 inches:	silty clay
										29-35 inches:	clay

Soil Map Unit	Percent of Area	Land-form(s)	Slope Range	Parent Material	Available Water Holding Capacity	Drainage	Saturated Hydraulic Conductivity Class	Restrictive Layer	Depth to Water Table	Typical Profile[1]	
				dense sandy alluvium						35 - 42 inches:	cemented silty clay loam
										42 - 60 inches:	sandy loam
Gridley Taxadjunct Clay Loam	10%	terraces on valleys	0 to 2 percent	clayey and loamy alluvium over cemented loamy alluvium	3.9 inches in top 5 feet	somewhat poorly drained	very low	duripan at 20 to 40 inches	15 to 20 inches	0 - 21 inches:	clay loam
										21 - 60 inches:	cemented coarse sandy loam
Gridley Taxadjunct-Calcic Haploxerolls Complex	3%	terraces on valleys	0 to 2 percent	loamy and clayey alluvium over cemented loamy alluvium	3.9 to 5.6 inches in top 5 feet	somewhat poorly to moderately well drained	very low to moderately low	duripan at 20 to 60 inches	15 to 43 inches	0 - 10 inches:	loam
										10 - 20 inches:	clay loam
										20 - 22 inches:	clay
										22 - 60 inches:	cemented material
Liveoak Sandy Clay Loam	2%	terraces on valleys	0 to 2 percent	channel deposited loamy alluvium	10.0 inches in top 5 feet	moderately well drained	high	none	30 to 65 inches	0 - 53 inches:	sandy clay loam
										53 - 60 inches:	sandy loam
Liveoak-Galt taxadjuncts complex	2%	flood plains on valleys	0 to 2 percent	loamy alluvium	4.4 to 10 inches in top 5 feet	somewhat poorly to moderately well drained	very low	duripan at 20 to 60 inches	17 to 51 inches	0 - 54 inches:	loam
										54 - 63 inches:	cemented material

Soil Map Unit	Percent of Area	Land-form(s)	Slope Range	Parent Material	Available Water Holding Capacity	Drainage	Saturated Hydraulic Conductivity Class	Restrictive Layer	Depth to Water Table	Typical Profile[1]	
										63 - 73 inches:	very fine sandy loam

1. For complexes, which contain a combination of distinct map units, the typical profile describes the primary map unit.

3.5.5 Climate

The climate statistics presented in this section are based on the Durham CIMIS station (#12) for the period October 1984 to September 2012. The station is located approximately 14 miles north of the district's service area and considered representative of BWGWD and the Feather River region as a whole.

BWGWD has a climate typical of the eastern Sacramento Valley, with mild winters with mild to moderate precipitation and warm to hot, dry summers. Average daily maximum temperatures range from a low of about 54°F in December to a high of approximately 91°F in July (Table 3.3). Mean daily minimum temperatures range from a low of approximately 37°F in January to a high of about 60°F in July.

Average annual reference evapotranspiration (ET_o) is approximately 49 inches, ranging from a low of one inch in December and January to a high of over seven inches in June and July. Approximately 75 percent of annual ET_o occurs in the six-month period from April through September.

Average annual precipitation is approximately 23 inches, with 17 inches or slightly more than 75 percent occurring in the five month period from November through March.

Even during the peak summer period, the average maximum relative humidity reaches 90 percent, which is indicative of an irrigated area, and remains near or above 90 percent throughout the year. Minimum relative humidity ranges between approximately 35 to 40 percent during the summer and roughly 50 to 65 percent during the wet winter months.

Average wind speed is lowest in August (3.5 miles per hour) and greatest during late winter and early spring, exceeding five miles per hour, on average.

There are no significant microclimates within the district that affect water management or operations.

Table 3.3. Mean Daily Weather Parameters by Month at Durham CIMIS Station (October 1984 to September 2012).

Month	Total ET_o (in)	Total Precip. (in)	Average Daily Temperature (F)			Average Relative Humidity (%)			Average Wind Speed (mi/hr)
			Avg.	Min.	Max.	Avg.	Min.	Max.	
January	1.1	4.3	45.4	37.2	54.9	81	64	95	4.6
February	1.9	3.8	49.7	39.5	61.0	73	52	92	5.2
March	3.2	3.0	53.7	42.0	66.1	69	46	92	5.2
April	4.6	1.4	59.0	45.5	72.6	62	38	89	5.0
May	6.2	1.2	66.0	52.1	79.7	58	36	88	4.9
June	7.1	0.7	72.1	57.7	86.2	57	36	87	4.6
July	7.2	0.1	75.7	60.3	90.9	60	38	90	3.7
August	6.4	0.1	73.9	58.1	90.2	59	36	90	3.5
September	4.9	0.4	69.8	54.5	86.9	57	33	88	3.7
October	3.4	1.4	61.8	48.3	78.0	59	34	87	3.9
November	1.6	2.5	51.1	40.3	63.9	73	49	92	4.1
December	1.1	3.7	44.5	36.1	54.3	79	61	94	4.7
Annual	48.8	22.7	60.2	47.6	73.7	66	44	90	4.4

3.5.6 Operating Rules and Regulations

The district's operating rules and regulations (R&Rs) are occasionally reviewed and revised as needed to address changing conditions. The R&Rs prescribe conditions that ensure distribution of irrigation water to users in an orderly, efficient and equitable manner; they are available to water users in pamphlet form and are included at the end of this chapter for convenient reference (Attachment 3.10.2).

3.5.7 Water Delivery Measurement and Calculation

BWGWD has completed substantial changes to improve delivery measurement in recent years in order to comply with the delivery measurement requirements of the Water Conservation Act of 2009 (SBx7-7) and California Code of Regulations Title 23 §597 (CCR 23 §597). The measurement requirements of SBx7-7 state that agricultural water suppliers subject to the law shall measure the volume of water delivered to customers with sufficient accuracy to (1) enable reporting of aggregated farm-gate delivery data to the state and (2) adopt a pricing structure for water customers based at least in part on the quantity of water delivered. In addition, CCR 23 §597 specifies minimum accuracy requirements for delivery measurement devices and requires certification of volumetric delivery measurement accuracy by a California registered professional engineer.

During the 2012 Irrigation Season, BWGWD tested a measurement device called the RemoteTracker that, when used at all gravity turnouts within BWGWD, would bring the district fully into compliance with the new measurement requirements described above. After the 2012

irrigation season, the board of directors approved the device, and BWGWD is implementing the RemoteTracker for delivery measurement throughout the district as funding allows. BWGWD is currently a party to a test claim pending before the Commission on State Mandates seeking reimbursement for compliance with the Water Conservation Act. The measurement data will be used as a basis for instituting volumetric billing under a volumetric rate structure adopted through a Proposition 218 process in early 2015. Additional detail describing BWGWD's delivery measurement improvement program is provided at the end of this chapter (Attachment 3.10.3).

3.5.8 Water Rate Schedules and Billing

Historically, BWGWD has billed for irrigation water deliveries to customers in its primary service area on a flat rate, per-acre basis, plus a stand-by charge. The standby charge, as of 2015, is $2 per acre. On March 8, 2015, completed a Proposition 218 process to adopt a water rate based in part on the volume of water delivered to meet the requirements of the CWC. As part of the process, BWGWD completed a rate study to evaluate revenues required to offset the district's cost of service. The adopted rate includes a fixed (per acre) rate component and a volumetric (per acre-foot) rate component. During full supply years, the fixed rate component is designed to recover approximately 75 percent of the cost of service, and the volumetric rate component is designed to recover approximately 25 percent of the cost of service. During curtailment years, the rate is increased in proportion to the reduction in available surface water supplies to recover approximately one half of the revenue lost through reduced water sales.

In addition to differences in the water rate between full supply and curtailment years, the water rate differs between gravity deliveries and deliveries to lands for which lift pumps a required to pump water for drains for irrigation. The water rate for these lands is reduced based on the estimated landowner cost per acre-foot to pump the water for irrigation. The reduction recognizes the avoided cost to the district of expanding gravity delivery canals or installing district lift pumps to provide deliveries in these areas.

Finally, a separate water rate applies to summer (April to October) and winter (November to January) deliveries. For both summer and winter deliveries, the fixed rate component is proportional to the estimated average duty, and the volumetric rate is the same for all land uses. The water rate is determined as follows:

- Summer Gravity Deliveries
  - Rice: $23.50/ac + $1.25/af
  - Orchard: $15.50/ac + $1.25/af
  - Row Crop: $13.50/ac + $1.25/af
  - Pasture: $17.50/ac + $1.25/af
- Summer Drain Deliveries
  - Rice: $5.50/ac + $0.25/af
  - Orchard: $3.50/ac + $0.25/af
  - Row Crop: $3.00/ac + $0.25/af
  - Pasture: $4.00/ac + $0.25/af

- Winter Gravity Deliveries
  - Straw Decomp.: $10.00/ac + $1.25/af
  - Duck Ponds/Habitat: $14.50/ac + $1.25/af
  - Orchard/Pasture (one flood): $3.50/ac + $1.25/af
- Winter Drain Deliveries
  - Straw Decomp.: $2.00/ac + $0.25/af
  - Duck Ponds/Habitat: $3.50/ac + $0.25/af
  - Orchard/Pasture (one flood): $1.00/ac + $0.25/af

Additionally, BWGWD provides certain water supplies to tertiary diverters within its sphere of influence, as defined by the Butte Local Agency Formation Commission (LAFCO). This water is available at the volumetric rate of $3.15 per acre-foot.

Standby assessments are issued in a single installment due in July of each year. Two applications for water service, one for summer water and one for winter water, are made annually by customers in the service area. For each application, the landowner specifies the FSA Field number, irrigated acreage, and type of irrigation, along with landowner information.

For the 2015 irrigation season, BWGWD billed customers for irrigation water using the rate structure above, except that the volumetric component of the rate was calculated based on estimated duties (applied water requirements) by crop as follows:

- Summer
  - Rice: 5.75 af/ac
  - Orchards: 3.85 af/ac
  - Row Crops: 3.30 af/ac
  - Pasture: 4.30 af/ac
  - Duck Ponds/Habitat: 6.40 af/ac
- Winter
  - Straw Decomp.: 2.40 af/ac
  - Duck Ponds/Habitat: 3.60 af/ac
  - Orchard/Pasture (one flood): 0.90 af/ac

Historically, bills were issued at the time of application. The first half of the bill was required to be paid before water delivery, and the second half was due before July 1. In the event of a crop idling transfer, 100% of the bill was due at the time of the application. A penalty could be assessed to customers not submitting payment by the specified due date. One application for water service was made annually by tertiary diverters within the sphere of influence.

With the adoption of a pricing structure based in part on the volume of water delivered, BWGWD is considering options to modify its billing practices. Options include requiring payment for the fixed charge before water delivery, with the volumetric charge due following the irrigation season.

Alternatively, some portion of the fixed charge could be made due prior to delivery, with the remainder of the fixed charge due along with the volumetric charge at some later date. In making modifications to its billing practices, BWGWD will consider financial considerations of different options to both the district and its customers.

3.5.9 Water Shortage Allocation Policies and Drought Management Plan

On April 1, 2015 Governor Brown issued Executive Order B-29-15, mandating agricultural water suppliers to include a detailed Drought Management Plan (DMP) describing actions and measures taken to manage water demand during drought. BWGWD has historically experienced very reliable surface water supplies with a full surface water supply of 161,000 acre-feet available in all but four years (1977, 1991, 1992, and 2015) since construction of Lake Oroville and its subsequent 1969 settlement agreement with the State. During years in which curtailment is allowed under the agreement, BWGWD's water supply can be reduced by up to approximately 50 percent, as discussed in greater detail in the attached DMP (Section II.3.10.5).

The DMP describes and expands upon BWGWD's shortage allocation policies, including discussion of a broad range of actions undertaken during drought to manage available water supplies and meet customer demands to the maximum extent possible.

The DMP includes components recommended by DWR in its 2015 AWMP Guidebook (DWR 2015). BWGWD's DMP describes the determination of available water supply, drought responses, and water shortage impacts. The description of water shortage impacts includes a discussion of 2015 supply and demand conditions available at the time of preparation of this DMP. A description of supplies and demands for 2013 and 2014, also required under Executive Order B-29-15, is included in the water balance section of this AWMP (II.3.7).

3.5.10 Policies Addressing Wasteful Use of Water

BWGWD actively prohibits the wasteful use of water, as described in its R&Rs (Attachment II.3.10.2). Enforcement actions include withholding water for wasteful use. The district's policies regarding unauthorized uses of water and enforcement are described in detail in the R&Rs. Water use that could be considered waste within the district remains available to provide groundwater recharge or is available downstream for agricultural or environmental water uses; regardless, the district actively prohibits excessive water use.

3.6 Inventory of Water Supplies

3.6.1 Introduction

This section provides a brief description of surface water and groundwater supplies within BWGWD as well as a description of BWGWD water quality monitoring practices.

3.6.2 Surface Water Supply

As described in Section 3.5.1, BWGWD is entitled to approximately 161,000 af of the Joint Districts allowed diversions from the Feather River under its 1969 agreement with the State, which is based on a pre-1914 water right and subject to reduction under certain conditions, as described previously. In addition to its individual allotment of the Joint Districts water supply, BWGWD has historically purchased portions of unused allotments from other of the Joint Districts. Additionally, BWGWD and individual water users within BWGWD reuse surface water entering the district from RID and BWD.

3.6.3 Groundwater Supply

BWGWD overlies the East Butte subbasin of the Sacramento Valley groundwater basin. The water-bearing formations of the East Butte subbasin consist of a combination of Holocene, Pleistocene, and Pliocene deposits and alluvium. The formations, size, and other features of the subbasin are described in Volume I, Section 2.7.2 of this AWMP.

BWGWD has a history of actively participating in groundwater management initiatives in the East Butte subbasin and Butte County as a whole. Most recently, BWGWD has embarked on the implementation of the Sustainable Groundwater Management Act of 2014 (SGMA) as a local Groundwater Sustainability Agency (GSA). SGMA represents a major shift in the management of California's groundwater resources, allowing local agencies to prepare and adopt Groundwater Sustainability Plans (GSPs) tailored to achieving sustainability of underlying groundwater basins and subbasins through local actions. For the East Butte subbasin, which has been designated a medium priority basin under the Law, a GSP or combination of GSPs addressing the entirety of the East Butte subbasin must be prepared and adopted by January 31, 2022. Within each subbasin, several options exist, including the following:

- One GSA representing the entire subbasin preparing a single GSP,
- Multiple GSAs representing the entire subbasin preparing a single GSP,
- Multiple GSAs representing the entire subbasin preparing multiple, coordinated GSPs.

At the time of preparation of this AWMP, the following agencies had elected to form GSAs in the East Butte subbasin:

- Richvale Irrigation District (9/1/2015)
- Biggs-West Gridley Water District (9/24/2015)
- Butte Water District (10/1/2015)
- Western Canal Water District (10/15/2015)
- Sutter Extension Water District (10/27/2015)
- County of Butte (10/27/2015)

Moving forward, BWGWD will actively collaborate with other GSAs and eligible interested parties in the subbasin to sustainably manage available groundwater resources. The development and use of surface water supplies by BWGWD and others over the past century has greatly contributed to the

sustainability of the groundwater system through beneficial recharge and prevention of pumping that would otherwise have occurred.

Prior to SGMA, BWGWD adopted an AB3030 compliant groundwater management plan (GMP) in 1995 with the purpose of managing and monitoring groundwater resources within the district boundary (BWGWD 1995). As part of GMP implementation, BWGWD coordinates and cooperates with other local water management entities to preserve, protect, and monitor groundwater extraction, distribution, and allocation within the basin. Components of BWGWD's GMP include the following:

- Control of saline water intrusion,
- Identification and management of well head protection areas and recharge areas,
- Regulation of migration of contaminated groundwater,
- Administration of a well abandonment and well destruction program,
- Mitigation of overdraft conditions,
- Replenishment of groundwater extracted by water producers,
- Groundwater level and storage monitoring,
- Development of relationships with State and Federal regulatory agencies,
- Facilitation of conjunctive use operations, and
- Implementation of the groundwater management plan.

Additionally, as a member of the Butte Basin Water Users Association, BWGWD was a participant in the development of the Butte County GMP finalized in 2004. The Butte County GMP accomplishes the following (CDM 2004):

- Supports the long-term maintenance of high quality groundwater resources within the county for agricultural, environmental, rural domestic and urban needs;
- Documents the county's existing groundwater management programs;
- Describes potential actions to increase the effectiveness of groundwater management; and
- Meet requirements of available grant funding opportunities.

Objectives of the Butte County GMP include the following:

- Minimize the long-term drawdown of groundwater levels,
- Protect groundwater quality,
- Prevent inelastic land surface subsidence resulting from groundwater pumping,
- Minimize changes to surface water flows and quality that directly affect groundwater levels or quality,
- Minimize the effect of groundwater pumping on surface water flows and quality,
- Evaluate groundwater replenishment and cooperative management projects, and
- Provide effective and efficient management of groundwater recharge projects and areas.

In addition to developing the Butte County GMP, the county board of supervisors approved a groundwater management ordinance in 2004 to support the development of quantitative Basin Management Objectives (BMOs). Specific BMOs address the following:

- Groundwater levels,
- Groundwater quality, and
- Inelastic land subsidence,

BWGWD does not own any groundwater wells. Total groundwater pumping within BWGWD for irrigation and wildlife habitat (primarily at the Gray Lodge Wildlife Area) is estimated to be approximately 6,000 af annually in recent years. It is estimated that there are more than 100 operable irrigation wells within the BWGWD service area with the potential to supplement surface water supplies. Additional pumping occurred in 2015 in response to curtailment of the district's Feather River supplies. Preliminary estimates of pumping in 2015 are provided in Section II.3.10.5.

3.6.4 Other Water Supplies

BWDWD does not have access to water supplies other than those described previously in section 3.6.

3.6.5 Water Quality Monitoring Practices

BWGWD does not actively monitor surface or groundwater quality; however, water quality monitoring is conducted within BWGWD and the surrounding region and allows for assessment of the quality of water for agricultural and habitat uses within the district service area.

Water quality monitoring is conducted by CDFW as part of management of the Gray Lodge Wildlife Area, and monitoring results are available to the district. The agreement between USBR and BWGWD for conveyance of water to Gray Lodge specifies water quality criteria for delivered water (CDFW 2010). Monitoring of water received by Gray Lodge has also been conducted by the Central Valley Regional Water Quality Control Board (CVRWQCB 1989), including BWGWD canal deliveries, agricultural drain water, and groundwater. The monitoring results indicate that the water quality of these three sources is good for irrigation and does limit the beneficial use of water for wildlife habitat.

Additional water quality monitoring in the vicinity of BWGWD has been performed in the past by DWR, the U.S. Geological Survey, the county, other water suppliers, and through water quality coalitions.

Butte County monitors groundwater quality at a network of 14 wells distributed among county subinventory units. Monitoring is conducted as part of implementation of the Butte County GMP adopted in 2004, though monitoring actually began in 2002. Water quality parameters monitored include temperature, pH, and electro conductivity.

Growers within BWGWD participate in the Sacramento Valley Water Quality Coalition and/or the California Rice Commission Coalition, which conduct monitoring of surface water quality in compliance with the CVRWQCB's Irrigated Lands Regulatory Program (ILRP). The monitoring program includes sampling and testing of a host of parameters for hundreds of samples collected annually from sites strategically distributed throughout the Sacramento River basin, which includes the Feather River region.

BWGWD is a party to a settlement agreement with DWR and three other districts (BWD, RID and WCWD) that addresses yield losses from lower water temperatures that result from the operation of Lake Oroville, as compared to pre-reservoir conditions. As part of the process to develop the settlement agreement, BWGWD, DWR, and the other districts developed and implemented a method to estimate rice yield reductions through detailed monitoring of water temperatures and yields.

In 2014, NCWA prepared a groundwater quality assessment report for the Sacramento Valley to evaluate the sources of salt and nitrate loads and potential long-term effects on surface water and groundwater resources. This information supports understanding of sustainable management of surface water and groundwater supplies, including conjunctive management opportunities and limitations. The primary objectives of the assessment were to (1) identify where known groundwater quality impacts exist, (2) prioritize high vulnerability areas, and (3) evaluate opportunities to incorporate existing groundwater monitoring efforts to achieve water management objectives.

3.7 Water Balance

3.7.1 Overview

This section describes the various uses of water within BWGWD between 1999 and 2014, followed by detailed water balances for key accounting centers within the district. Water balances are presented for the distribution and drainage system (i.e. canals and drains), farmed lands, and the district as a whole. The water balances quantify all substantial inflows to and outflows from the BWGWD service area on a water year basis (October – September). The period from 1999 to 2014 has been chosen because it depicts recent water management conditions. Key drivers of water management variability across years include precipitation timing and amounts and crop idling for water transfers. Limited supplies in years of surface water reduction are also a strong driver but did not occur between 1999 and 2014. It is anticipated that the water balance analysis will be updated to reflect curtailment in 2015 as part of the next AWMP update. Conditions in 2015 are discussed in greater detail in the Drought Management Plan, included as Section II.3.10.5 of this AWMP.

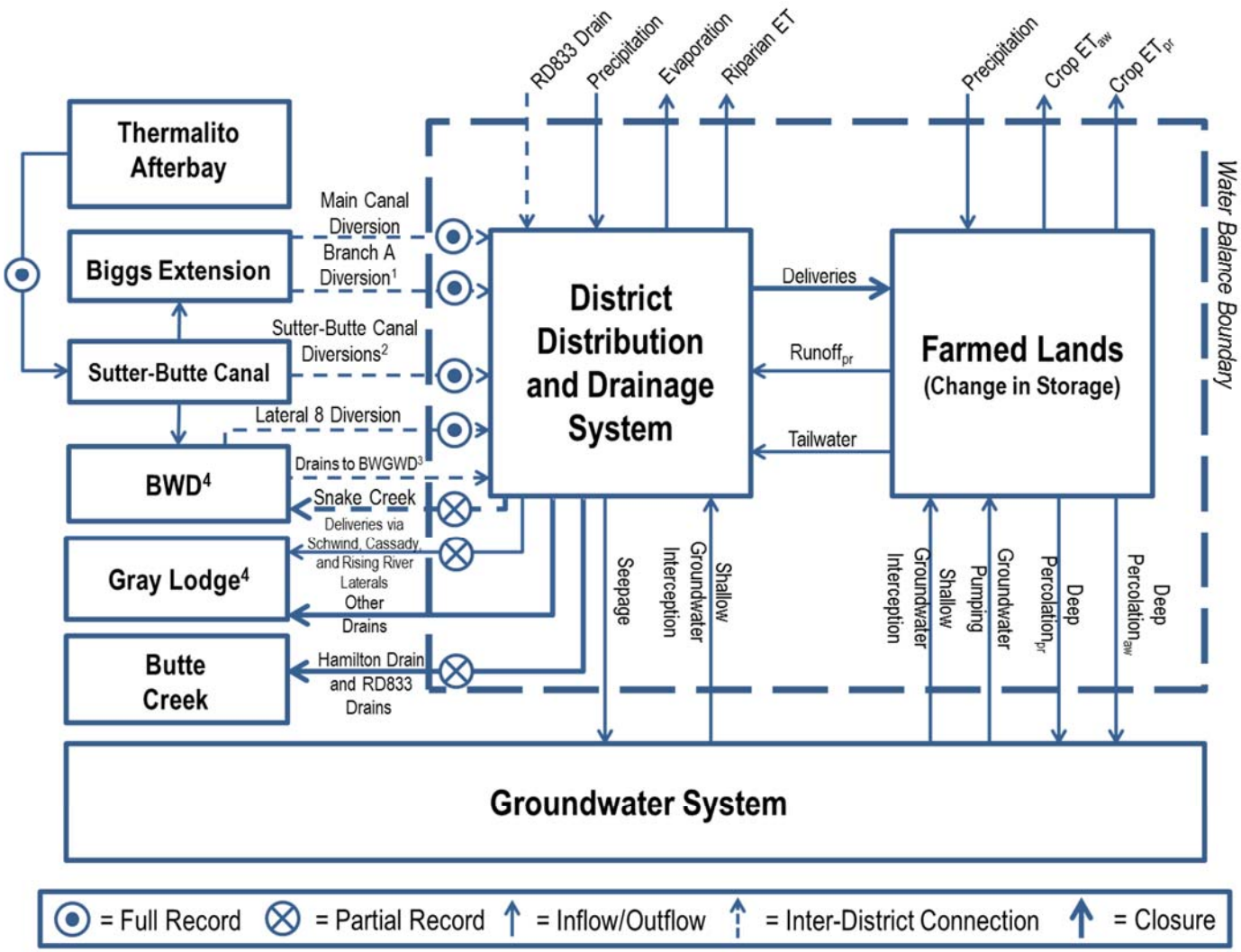
Historical estimates of water use differ slightly from those presented in BWGWD's 2014 AWMP as a result of refinements to the analyses used to develop the estimates, but fall within the range of uncertainty presented in Table 3.4 and do not affect conclusions regarding water management conditions within BWGWD.

The remainder of this section includes the following subsections:

- Analytical Approach – Description of mass balance approach for water balance analysis, methodologies for estimation of individual flow paths, and uncertainty in flow path estimates;
- Water Uses – Description of water use for agricultural, environmental and recreational, municipal and industrial, groundwater recharge, and transfer and exchange purposes;
- Drainage – Description of drainage occurring within and flowing from the district; and
- Water Accounting (Water Balance Summary) – Summary of monthly and annual inflows to and outflows from the district, including a discussion of existing water management and performance.

3.7.2 Analytical Approach

The BWGWD water balance includes separate accounting centers for the distribution and drainage system and the farmed lands within the service area. A total of 25 individual flow paths are estimated. A schematic of the water balance structure is provided in Figure 3.3. The schematic identifies sources and destinations of water, accounting centers, and individual flow paths by which water enters and leaves the system.



1. Branch A Diversion also includes other deliveries from Biggs Extension.
2. Sutter-Butte Canal Diversions include deliveries to turnouts, private ditches, and drains directly from Sutter-Butte Canal.
3. Drains to BWGWD include Hamilton Drain, Brooks Drain, Meyers Drain, and other tributaries and drains.
4. BWD is Butte Water District, and Gray Lodge is Gray Lodge Wildlife Area.

Figure 3.3. Water Balance Structure.

Mass Balance

In general, flow paths are quantified on a monthly basis. For each accounting center, water volumes associated with certain flow paths are estimated independently based on measured data or calculated estimates, and the remaining flow is then calculated based on the principal of conservation of mass (Equation 3.1), which states that the difference between total inflows to and total outflows from an accounting center for a given period of time is equivalent to the change in stored water within that accounting center. For the distribution and drainage system, the change in storage is assumed to be zero on a monthly basis. For the farmed lands, the monthly change in storage varies, reflecting changes in the volume of water ponded in rice and managed wetlands areas as well as changes in soil moisture stored in the root zone. Over the course of a year the change in storage across all farmed lands is expected to be near zero.

$$Inflows - Outflows = Change\ in\ Storage\ (monthly\ time\ step) \qquad [3.1]$$

The flow path that is calculated based on Equation 3.1 is referred to as the "closure term" because the mass balance equation is solved for or "closed" on the unknown quantity. The closure term is selected based on consideration of the availability of data or other information to support an independent estimate as well as the volume of water representing the flow path relative to the size of other flow paths. Generally speaking, the largest, most uncertain flow path is selected as the closure term.

Flow Path Estimation and Uncertainty

Individual flow paths were estimated based on direct measurements or based on calculations using measurements and other available data. As described previously, those flow paths not estimated independently were calculated as the closure term of each accounting center.

The analysis results for each flow path are reported with a high level of precision (nearest whole acre-foot) that implies a higher degree of accuracy than is actually justified. The estimated percent uncertainty (approximately equivalent to a 95 percent confidence interval) in each measured or calculated flow path has been estimated as part of the water balance analysis. Based on the relative magnitude of each flow path, the resulting uncertainty in each closure term can be estimated by assuming that errors in estimates are random (Clemmens and Burt 1997). Errors in estimates for individual flow paths may cancel each other out to some degree, but the combined error due to uncertainty in the various estimated flow paths is ultimately expressed in the closure term.

For the distribution and drainage system accounting center, aggregated surface outflows were calculated as the closure term, based on the assumption that the change in storage over time is zero. Total outflows were distributed across each individual outflow waterway (i.e. creeks and drains) based on available outflow measurements and estimated drainage areas tributary to each outflow location. Aggregated surface outflows were selected as the closure term because of the combination of the lack of available outflow data, generally large magnitude, and relative uncertainty of the flow path.

For the farmed lands accounting center, deliveries were calculated as the closure term. Deliveries were selected as the closure term because historical measurements were not readily available for the full period of analysis and they represent the largest inflow into the farmed lands accounting center. Deliveries calculated via closure include deliveries by BWGWD from its canals, laterals, and drains, as well as any district or private reuse of water or unaccounted groundwater pumping.

Table 3.4 lists each flow path included in the water balance indicating which accounting center(s) it belongs to; whether it is an inflow or an outflow; whether it was measured or calculated; the supporting information and assumptions used to determine it; the estimated uncertainty, expressed as a percent; and average values for the period of analysis. Results for both the full water year and for the primary irrigation season (April to September) are provided. As indicated, estimated uncertainties vary from 5% to 100% of the average volume for the irrigation season, with uncertainties generally being less for measured flow paths and greater for calculated flow paths.

The estimated uncertainty of each closure term is also shown. As indicated, the estimated uncertainty in aggregated surface outflows is 23% for the water year as a whole and 29% for the irrigation season. The estimated uncertainty in deliveries is 15% for the water year as a whole and 13% for the irrigation season. The uncertainty in deliveries decreases for the irrigation season due to the lack of precipitation from winter storms.

Table 3.4. Water Balance Flow Paths, Supporting Data, and Estimated Uncertainty.

Account-ing Center	Flow Path Type	Flow Path	Source	Supporting Data	Water Year (Oct. - Sept.)		Irrigation Season (Apr. - Sept.)	
					Average Volume (af)	Estimated Uncertainty	Average Volume (af)	Estimated Uncertainty
Distribution and Drainage System	Inflow	Main Canal Diversion	Measurement	Joint Water Districts Board Measurement Site	194,046	10%	140,243	10%
		Branch A Diversion	Measurement	Joint Water Districts Board Measurement Site	4,966	15%	3,683	15%
		Sutter-Butte Canal Diversions	Measurement	Joint Water Districts Board Measurement Site	17,953	15%	13,447	15%
		Lateral 8 Diversion	Measurement	Joint Water Districts Board Measurement Site	7,195	15%	5,180	15%
		RD833 Drains	Calculation	Calculated in RID Water Balance	44,755	17%	21,583	26%
		Drains from BWD	Calculation	Calculated in BWD Water Balance	22,554	45%	15,851	46%
		Precipitation	Calculation	Quality-controlled precipitation from CIMIS, estimated canal surface area	402	15%	59	15%
		Shallow Groundwater Interception	Calculation	Estimated as closure of regional water balance. Distributed within region based on area, drain miles, and average depth to groundwater.	9,095	70%	9,269	70%
		Runoff of Precipitation	Calculation	IDC analysis, NRCS soils characteristics, CIMIS precipitation data	21,063	25%	2,078	25%
		Tailwater	Calculation	Estimated as 35% percent of Deliveries	56,762	30%	47,661	30%
	Outflow	**Deliveries (to Farmed Lands)**	**Closure (Farmed Lands)**	**Closure term of Farmed Lands Water Balance**	**162,176**	**15%**	**136,174**	**13%**
		Deliveries via Schwind, Cassady, and Rising River Laterals	Calculation	USBR Gray Lodge Wildlife Area Data	27,551	15%	12,733	15%
		Evaporation	Calculation	CIMIS reference ET, estimated evaporation coefficient, estimated wetted surface area	1,045	15%	830	15%
		Riparian ET	Calculation	CIMIS reference ET, estimated crop coefficient based on 2009 SEBAL analysis, estimated riparian area	210	15%	154	15%
		Seepage	Calculation	NRCS soils data, published seepage rates by soil type, estimated wetted area, estimated wetted duration	18,076	35%	10,674	35%
		Snake Creek	**Closure (Distribution and Drainage System)**	**Difference between total inflows and measured/estimated outflows for Distribution and Drainage System accounting center, distributed according to drainage area and available data, BWGWD Operational Data, California Water Data Library Sites A00910 and A02980**	**22,065**	**23%**	**12,804**	**29%**
		Other Drains			**33,947**		**19,698**	
		Hamilton and RD833 Drains			**113,721**		**65,988**	
Farmed Lands	Inflow	Precipitation	Calculation	Quality-controlled precipitation from CIMIS station, reported cropped area	53,131	15%	7,839	15%
		Deliveries	**Closure (Farmed Lands)**	**Difference between measured/estimated inflows and total outflows for Farmed Lands accounting center, including estimated Tailwater as percentage of Deliveries**	**162,176**	**15%**	**136,174**	**13%**
		Shallow Groundwater Interception	Calculation	Estimated as closure of regional water balance. Distributed within region based on area, drain miles, and average depth to groundwater.	3,032	70%	3,090	70%
		Groundwater Pumping	Calculation	Estimated based on applied water demand for groundwater only acres, plus Gray Lodge historical pumping within BWGWD.	5,303	25%	2,932	25%
	Outflow	Tailwater	Calculation	Estimated as 35% percent of Deliveries	56,762	30%	47,661	30%
		Crop ET of Applied Water	Calculation	CIMIS reference ET; estimated crop coefficients based on SEBAL 2009 analysis; crop acreages from Joint Board records, DWR land use surveys, and agricultural commissioner crop reports; Integrated Water Flow Model Demand Calculator (IDC) analysis to divide total ET into applied water and precipitation components	88,018	10%	69,056	10%
		Crop ET of Precipitation	Calculation		22,550	10%	14,364	10%
		Runoff of Precipitation	Calculation	IDC analysis, NRCS soils characteristics, CIMIS precipitation data	21,063	25%	2,078	25%
		Deep Percolation of Applied Water	Calculation	IDC analysis, NRCS soils characteristics, CIMIS precipitation data, Integrated Water Flow Model Demand Calculator (IDC) analysis to divide total deep perc. into applied water and precipitation components	27,601	35%	15,080	35%
		Deep Percolation of Precipitation	Calculation		7,883	35%	2,861	35%
	Change in Storage		Calculation	IDC Analysis	-235	50%	-1,068	50%

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3.7.3 Water Use

The district supplies agricultural irrigation water and also provides water for environmental use to provide wildlife habitat within and outside its service area. These water uses are described in greater detail in the remainder of this section.

Agricultural

Agricultural irrigation is by far the dominant water use in BWGWD. Between 1999 and 2014, there were an average of 25,400 cropped acres within the district's service area, with an average of 1,200 additional acres of fallow or idle land.

Table 3.5 and Figure 3.4 present estimated irrigable acreages for this period. As indicated, the main crop in the district is rice, which was grown on an average of 21,600 acres between 1999 and 2014, representing 85% of the total cropped area, or 81% of the irrigable area. Orchards account for an average of 1,800 acres or 7% if the cropped area. Other crops such as grain, hay, and pasture account for an average of 2,000 acres or 8% of the cropped area. The acreage of other crops has decreased over time.

Crop acreage decreased in 2010, 2012, and 2014 as a result of crop idling-based water transfers. Cropped acreage within these years averaged 21,900 acres, with an average of 26,200 acres in years in which cropland was not idled for transfer.

Table 3.5. Crop and Idle Acres, 1999-2014[6].

Year	Crop Acreage by Type					
	Rice	Orchards	Other	Idle	Total Cropped	Total with Idle
1999	22,108	1,932	2,896	127	26,935	27,062
2000	22,213	1,858	2,589	193	26,659	26,852
2001	20,616	1,875	3,400	278	25,891	26,169
2002	20,937	1,614	3,345	330	25,896	26,226
2003	21,923	1,579	2,634	392	26,136	26,528
2004	22,581	1,497	1,606	461	25,684	26,145
2005	22,868	1,853	1,533	437	26,254	26,691
2006	22,601	1,723	1,532	489	25,857	26,346
2007	22,541	1,753	1,528	497	25,822	26,319
2008	23,113	1,737	1,772	455	26,622	27,077
2009	23,104	1,732	1,432	485	26,268	26,754
2010	19,654	1,777	1,505	4,157	22,937	27,094
2011	22,466	1,956	1,530	487	25,952	26,439
2012	19,306	1,761	1,457	4,359	22,524	26,883
2013	22,636	2,157	1,336	423	26,128	26,551
2014	16,821	2,180	1,317	6,109	20,318	26,427
Average	**21,593**	**1,812**	**1,963**	**1,230**	**25,368**	**26,598**

[6] Acreages reported in Table 3.5 are estimated based on available DWR crop surveys, agricultural commissioner crop reports, and satellite-based land use estimates and may differ somewhat from cropping estimates prepared by the Joint Water Districts Board.

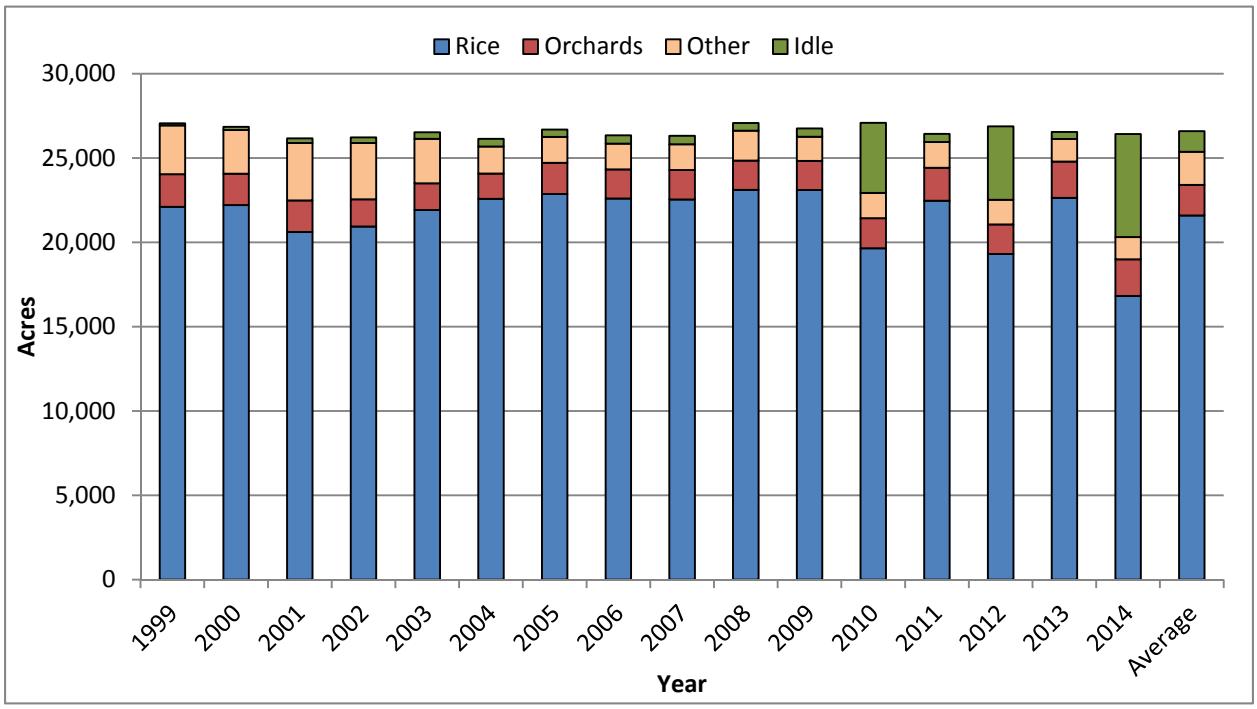

Figure 3.4. Crop and Idle Acres, 1999-2014[7].

Crop evapotranspiration (ET) was estimated using a crop coefficient approach, whereby estimated crop- and time-specific water use coefficients were multiplied by reference ET (ET_o) to calculate the total consumptive use of water for the farmed lands over time. Crop coefficients specific to the Sacramento Valley were developed based on actual ET estimates from a remote sensing analysis using the Surface Energy Balance Algorithm for Land (SEBAL). The analysis used ground and satellite data to compute actual ET from March to September for individual 30-meter satellite pixels within Glenn and Colusa counties in 2009. Spatially distributed cropping data from DWR land use surveys for Glenn and Colusa counties for 2009 were combined with quality-controlled reference evapotranspiration (ET_o) from CIMIS to calculate crop coefficients representing actual ET over the course of the growing season[8]. A map showing March to September ET estimates for BWGWD from SEBAL for 2009 is provided in Figure 3.5.

[7] Total acres vary somewhat from year to year reflecting estimated changes in total irrigable acres resulting from rural development and changes in areas of native vegetation.
[8] Ideally, the crop coefficient analysis would have included portions of Butte, Sutter, and Yuba counties within the Feather River region; however, DWR land use surveys were not available for 2009 for these counties. Crop coefficients developed for Glenn and Colusa counties are considered reasonably representative for the region as a whole.

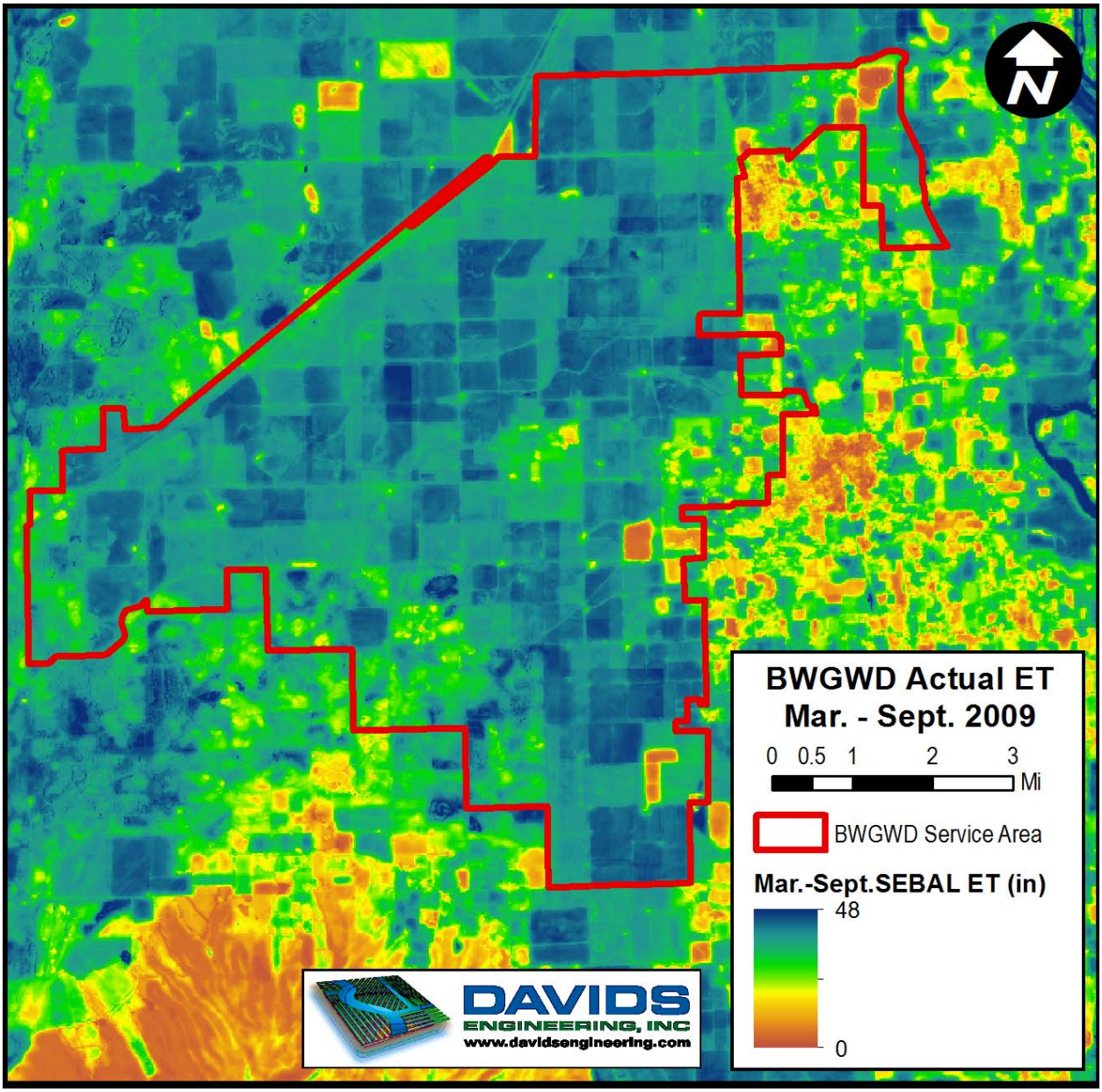

Figure 3.5. March to September 2009 SEBAL Actual ET.

A root zone water balance simulation was developed for each crop using the Integrated Water Flow Model (IWFM) Demand Calculator (IDC) Version 4.0 developed by DWR to estimate the portions of total ET derived from applied water (ET_{aw}) and from precipitation (ET_{pr}). ET values for each crop, expressed in units of acre-feet per acre were multiplied by the corresponding acreage in each year to compute total water volumes consumed for agricultural purposes.

For rice, the IDC model simulates ponding during the growing season and during the decomposition period in the fall and winter. As a result, precipitation occurring when ponds are full runs off of the fields and is not available to contribute to crop ET. Precipitation stored in the soil during the winter is available for extraction. For non-ponded crops, runoff and infiltration of precipitation are

modeled for individual precipitation events. Precipitation entering the soil may be stored and available to support crop ET, or it may leave the root zone as deep percolation. One result of the differences in irrigation and cultural practices between rice and non-ponded crops is that ET_{pr} is significantly less for rice. Additional detail describing rice water management is provided in Volume I, Section 2.

The monthly consumptive use of water in BWGWD ranges from approximately 1 inch of total ET in December and January to nearly 8 inches in June and July. A majority of ET is derived from applied water, and ET_{aw} ranges from approximately 1 inch in December and January to approximately 7.4 inches in July for the irrigable area. The average monthly consumptive use of water is presented in Figure 3.6.

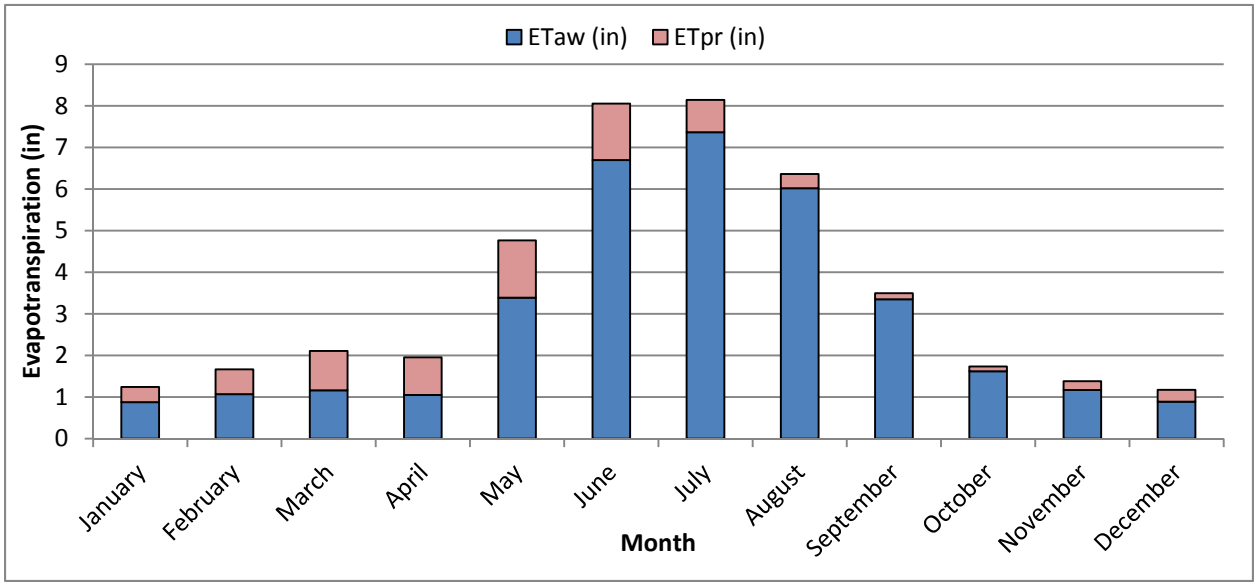

Figure 3.6. Average Monthly Consumptive Use of Water.

As indicated in Table 3.6, the annual consumptive use of water by crops in BWGWD ranges from approximately 45 inches of total crop ET for rice to approximately 35 inches for other crops. ET_{aw} ranges from approximately 24 inches to 39 inches. For rice, approximately 39 inches of the 45 inches of total ET are derived from applied irrigation water. On average, approximately 35 inches of 42 inches of total ET are derived from applied irrigation water district-wide.

Table 3.6. Average Acreages and Annual Evapotranspiration Rates by Crop.

Crop	Average Acres	Average Evapotranspiration (in)		
		ET_c	ET_{aw}	ET_{pr}
Rice	21,593	45.2	38.6	6.5
Orchards	1,812	37.4	25.3	12.1
Other	1,963	34.5	23.6	10.9
Idle	1,230	10.4	0.0	10.4
Totals	26,598	42.2	34.8	7.4

ET_c and ET_{aw} vary from year to year due to differences in atmospheric water demand (ET_o) and differences in the timing and amount of precipitation available to support crop growth and offset crop irrigation requirements. Total annual ET varied between approximately 97,000 af and 124,000 af during the 1999 to 2014 period, with an average annual volume of 111,000 af. On average, approximately 88,000 af of ET were derived from applied irrigation water (80% of total ET) and 23,000 af of ET were derived from precipitation (20% of total ET).

Other uses of applied irrigation water include winter flooding for habitat and rice straw decomposition (discussed in the following section), leaching of salts, and frost protection for orchard crops. Due to the low salinity of surface water diverted from the Feather River, the required leaching fraction is small for the crops grown in the district and has not been estimated at this time. Additionally, water applied for frost protection, if any, is typically applied outside of the irrigation season and is a minor use; thus, it has not been estimated at this time.

Environmental and Recreational

Managed wildlife habitat in BWGWD includes approximately 3,700 acres of the Gray Lodge Wildlife Area and 1,000 acres of the Butte Sink Wildlife Management Area. Additionally, it is estimated that more than 11,000 acres of the rice fields in BWGWD are typically flooded in the winter following harvest to aid in rice straw decomposition and to create winter habitat for migratory waterfowl and shorebirds along the Pacific Flyway. Use of water during the winter for rice straw decomposition and wetland habitat increased substantially between 1992 and 2001, largely driven by the phasing out of burning of rice straw as a result of the Connelly-Areias-Chandler Rice Straw Burning Reduction Act of 1991. Winter flooded acres have remained relatively steady since around 2000.

Diversions and estimated applied water for rice straw decomposition and wildlife habitat within BWGWD are provided in Table 3.7. These estimates are based on measured diversions and estimated applied water (delivery flow path from the water balance analysis) for the October – March period. Diversions are zero between February and March, although private reuse of available water may occur and is included in the estimated applied water.

Table 3.7. Estimated Winter Diversions and Applied Water for Managed Wetlands and Rice Straw Decomposition.

Water Year	Deliveries to Gray Lodge via Schwind, Cassady, and Rising River Laterals[1] (af)	Applied Water (af)[2]	Total Applied Water (af)
1999	14,326	28,273	42,599
2000	15,894	23,291	39,185
2001	15,199	27,229	42,428
2002	16,840	30,257	47,096
2003	17,859	21,975	39,835
2004	14,430	32,177	46,607
2005	16,100	17,842	33,942
2006	9,886	23,613	33,499
2007	7,053	33,460	40,513
2008	17,569	28,103	45,672
2009	16,885	28,312	45,197
2010	17,873	15,286	33,159
2011	15,628	26,648	42,276
2012	16,201	19,935	36,136
2013	12,749	37,325	50,074
2014	12,592	22,867	35,459
Average	14,818	26,037	40,855

Does not include deliveries to Gray Lodge during the irrigation season, only during the period from October through March.
2. Estimated based on water balance analysis. Includes deliveries plus reuse.

The water supplied during the winter period provides critical habitat to support migratory waterfowl and shorebirds while also creating recreational opportunities. Aside from this, there are no recreational water uses within the district.

In addition to use of water within the district to provide winter habitat, surface outflows from BWGWD flow to Butte Creek and Snake Creek (which can enter the Sutter Bypass through the Wadsworth Canal), providing important flows to support migration of salmon and steelhead and other downstream uses of water for wildlife habitat, such as diversions by Sutter National Wildlife Refuge to support seasonal wetlands. Outflows from the BWGWD service area are discussed in greater detail in the drainage and water balance sections.

Municipal and Industrial

BWGWD does not provide any municipal or industrial water.

Groundwater Recharge

Groundwater recharge that occurs within the district's service area consists of seepage from canals as well as deep percolation of precipitation and applied irrigation water. Distributed recharge through seepage and deep percolation provides a means to replenish the groundwater system to the benefit of BWGWD water users, the communities of Biggs and Gridley, other individuals within

BWGWD, and surrounding areas overlying the East Butte groundwater subbasin and Sacramento Valley groundwater basin.

Estimates of recharge were developed as part of the water balance analysis. Specifically, canal seepage estimates were calculated based on estimated soil hydraulic characteristics along with estimated canal wetted perimeters, overall lengths, and wetting frequency. Deep percolation of applied irrigation water and precipitation were calculated based on estimated applied irrigation water amounts over time as influenced by ET_o, precipitation, crop, and soil type, and simulated by the IDC model described previously.

Estimated annual seepage and deep percolation volumes for water years 1999 to 2014 are provided in Table 3.8, along with total recharge expressed as a volume and as a depth of water for each year.

Table 3.8. Total Groundwater Recharge, 1999-2014.

Water Year	Canal Seepage (af)	Deep Percolation of Applied Water (af)	Deep Percolation of Precipitation (af)	Total Recharge	
				af	af/ac
1999	18,414	27,411	8,287	54,112	1.7
2000	18,414	29,119	8,961	56,494	1.7
2001	18,414	28,298	6,692	53,404	1.6
2002	18,414	29,480	9,276	57,171	1.7
2003	18,414	27,173	9,877	55,464	1.7
2004	18,414	28,201	8,840	55,455	1.7
2005	18,414	27,407	10,011	55,832	1.7
2006	16,609	29,430	14,037	60,076	1.8
2007	18,414	28,477	2,716	49,607	1.5
2008	18,414	30,149	5,814	54,378	1.6
2009	18,414	29,115	4,176	51,705	1.6
2010	16,609	25,881	9,694	52,183	1.6
2011	18,414	27,285	14,279	59,978	1.8
2012	16,609	23,789	7,167	47,564	1.5
2013	18,414	26,936	4,674	50,025	1.5
2014	18,414	23,460	1,629	43,504	1.3
Average	18,076	27,601	7,883	53,560	1.6

Total recharge between 1999 and 2014 ranged from approximately 44,000 af to 60,000 af per year, or from 1.3 af to 1.8 af per acre per year. On average between 1999 and 2042, total recharge was estimated to be approximately 54,000 af per year (1.6 af/ac), with approximately 33% of recharge originating from canal seepage, 52% from deep percolation of applied water, and 15% from deep percolation of precipitation.

Groundwater level monitoring data and field observations suggest that the shallow groundwater system and regional aquifer are coupled within portions of BWGWD's service area at certain times and that an unsaturated aquifer zone may thus not be present to receive recharge. Depth to water in residential and irrigation wells is typically less than ten feet, and drains flow even when

irrigation is not occurring. These conditions likely result from limited groundwater pumping in the area along with sustained use of surface water for irrigation over past decades. As a result, it is likely that a substantial portion of the water percolating into the soil from ponded fields and seeping from canals is unable to flow downward but rather flows horizontally to where it is intercepted by non-ponded vegetation or by drains, providing base flow. Shallow groundwater interception is shown conceptually in Figure 3.7 and discussed in a regional context in Volume I of this AWMP.

Even in areas where an unsaturated zone is present, water infiltrating into the soil in ponded fields may encounter impermeable layers caused by plow pan or natural soil features and flow laterally to adjacent lands or provide base flow for drains. Additional information is needed to distinguish shallow groundwater interception in areas where the shallow and regional groundwater systems are coupled from areas with perched shallow groundwater.

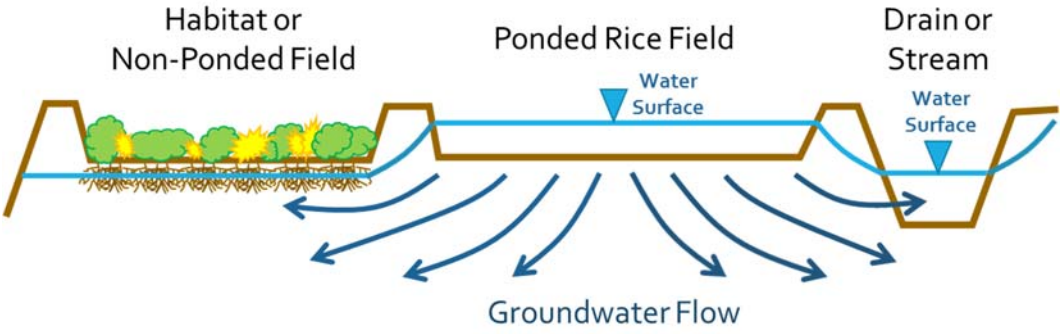

Figure 3.7. Conceptualization of Shallow Groundwater Interception in Rice Growing Areas.

Groundwater recharge net of well pumping and shallow groundwater interception represents the net amount of water contributing to groundwater storage from irrigation and precipitation processes in BWGWD. Net recharge was calculated by subtracting estimated pumping volumes from total recharge volumes. As described above, shallow groundwater interception occurs when drains, creeks, or other waterways intercept or "gain" water from the shallow groundwater system, which may be perched or connected to the regional aquifer. Additionally, shallow groundwater can be intercepted and consumed by natural or other non-ponded vegetation. Net annual recharge estimates for 1999 to 2014 are provided in Table 3.9.

Table 3.9. Net Groundwater Recharge, 1999-2014.

Water Year	Total Recharge (af)	Groundwater Pumping (af)	Shallow Groundwater Interception (af)	Net Recharge	
				af	af/ac
1999	54,112	4,098	12,127	37,887	1.2
2000	56,494	4,532	12,127	39,835	1.2
2001	53,404	3,929	12,127	37,348	1.1
2002	57,171	2,468	12,127	42,576	1.3
2003	55,464	6,051	12,127	37,286	1.1
2004	55,455	7,256	12,127	36,072	1.1
2005	55,832	6,788	12,127	36,917	1.1
2006	60,076	6,886	12,127	41,063	1.2
2007	49,607	5,416	12,127	32,064	1.0
2008	54,378	5,888	12,127	36,362	1.1
2009	51,705	5,914	12,127	33,664	1.0
2010	52,183	5,034	12,127	35,023	1.1
2011	59,978	4,437	12,127	43,413	1.3
2012	47,564	4,093	12,127	31,344	1.0
2013	50,025	5,218	12,127	32,679	1.0
2014	43,504	6,837	12,127	24,540	0.7
Average	53,560	5,303	12,127	36,130	1.1

Net recharge varied from approximately 25,000 af to 43,000 af per year between 1999 and 2014, or 0.7 af to 1.3 af per acre per year. On average between 1999 and 2014, net recharge was estimated to be approximately 36,000 af per year (1.1 af/ac-year).

Transfers and Exchanges

The district participated in voluntary water transfers in 2010, 2012, and 2014. All transfers were crop idling-based. Participating landowners idled land within the district and transferred the surface water that would have been consumed in lieu of the transfer. The quantity of water transferred was based on DWR estimates of the annual evapotranspiration of applied water for rice (3.3 af/ac). Estimates of idled acres and the amount of water transferred in 2010, 2012, and 2014 are provided in Table 3.10.

Table 3.10. Crop Idling Water Transfer Volumes, 1999-2014.

Year	Idle Acreage[1]	Transfer Volume (af)
2010	3,725	12,293
2012	4,912	16,210
2014	5,728	18,902

1. Acreages reported in Joint Board Reports.

Other Water Uses

Other incidental uses of water within BWGWD may include watering of roads for dust abatement or agricultural spraying. The volume of water used for such purposes is small relative to other uses and has not been quantified as part of this AWMP.

3.7.4 Drainage

Surface Outflows

Surface drains within BWGWD convey runoff of precipitation, surface inflows from upgradient lands, runoff of irrigation water (tailwater), and provide shallow groundwater relief by capturing canal seepage and intercepting shallow groundwater. Surface drains are also an important source of water for crop season irrigation and winter flooding in certain areas. All water leaving the district as surface outflow is available for downstream agricultural and environmental uses. Annual surface outflows are summarized in Table 3.11. Surface outflows during the irrigation season are approximately half of annual values.

Table 3.11. Estimated Surface Outflow Volumes, 1999-2014.

Water Year	Hamilton and RD833 Drains (af)	Snake Creek (af)	Other Drains (af)	Total Boundary Outflows (af)
1999	96,337	18,692	28,757	143,787
2000	107,298	20,819	32,029	160,146
2001	94,085	18,255	28,085	140,425
2002	106,220	20,610	31,708	158,538
2003	115,173	22,347	34,380	171,900
2004	150,217	29,147	44,841	224,205
2005	121,061	23,489	36,138	180,688
2006	153,207	29,727	45,734	228,668
2007	114,480	22,213	34,173	170,866
2008	111,679	21,669	33,337	166,685
2009	96,407	18,706	28,778	143,891
2010	114,844	22,283	34,282	171,409
2011	145,941	28,317	43,564	217,822
2012	120,066	23,296	35,841	179,203
2013	101,102	19,617	30,180	150,899
2014	71,421	13,858	21,320	106,598
Average	113,721	22,065	33,947	169,733

Water year boundary outflows ranged from approximately 107,000 af to 229,000 af between 1999 and 2014 with an average of 170,000 af. Based primarily on estimated tributary areas above each outflow location, total boundary outflows were divided among the three primary outflows. It is estimated that approximately two-thirds of total outflows flow to Butte Creek via Hamilton and 833 drains (some of which eventually reaches Butte Slough and the Sutter Bypass), 13% flow to Snake Creek and BWD, and 20% leave the district via other drains.

Tailwater

The farmed lands water balance includes an estimate of the volume of tailwater entering the distribution and drainage system that is available for reuse. A portion of this volume is reused internally by the district and individual water users and is included in the estimated deliveries; the remainder is available for reuse by downgradient water users along the Hamilton Drain and Butte Creek, in the Sutter Bypass, or in BWD. Table 3.12 presents the estimated annual tailwater volumes between water years 1999 and 2014.

Table 3.12. Estimated Tailwater Volumes, 1999-2014.

Water Year	Tailwater (af)
1999	57,142
2000	59,910
2001	60,982
2002	61,324
2003	55,838
2004	54,228
2005	53,367
2006	51,673
2007	66,565
2008	65,701
2009	60,743
2010	49,851
2011	48,349
2012	50,708
2013	60,296
2014	51,508
Average	56,762

Tailwater entering the distribution and drainage system between 1999 and 2014 ranged from approximately 48,000 af to 67,000 af per year. Average tailwater for this period was approximately 57,000 af per year.

Reuse

BWGWD operates six recovery pumps locations where water is pumped from drains back into the distribution system and reused downstream. Average drainwater reuse by BWGWD is estimated to be approximately 15,000 af annually. Substantial drainwater reuse also occurs within Gray Lodge and by other individual water users within the district. Reuse of drainwater within the portion of Gray Lodge located within the BWGWD service area is estimated to be approximately 10,000 af annually. Reuse by other individual water users is estimated to be approximately one third of reuse by the district, or 5,000 af. Reuse by BWGWD, CDFW at Gray Lodge, and individual water users reduces diversion requirements from the afterbay and results in district-scale water use efficiency that would otherwise not be attained. Implications of reuse at the district and regional scales are further discussed in the following section.

3.7.5 Water Accounting (Summary of Water Balance Results)

The BWGWD water balance structure was shown previously in Figure 3.3. The water balance was prepared for the distribution and drainage system and for farmed lands. Additionally, the water balance can be summarized for the BWGWD service area as a whole ("Water Balance Boundary" shown in Figure 3.3). An accounting center representing the groundwater system is also included in Figure 3.3 to account for exchanges between the root zone and the underlying groundwater system; however, a complete balance for the underlying aquifer has not been developed because not all inflows and outflows into the groundwater system (such as horizontal boundary flows) have been estimated.

As depicted in Figure 3.3 and discussed previously, interconnection exists between the accounting centers due to recapture and reuse of water by both BWGWD and by individual water users. Specifically, surface runoff of applied water (tailwater) flows back into the distribution and drainage system. Within the drainage system, reuse of water originating as tailwater, operational spillage, or from other sources is practiced by the district and by individual water users, including water managers at Gray Lodge. This water recovery and reuse results in higher levels of aggregate performance than would otherwise occur.

The water balance results are presented on a water year basis for 1999 through 2014. Underlying the annual time step is a more detailed water balance in which all flow paths are estimated on a monthly basis.

District-Wide and Individual Accounting Center Water Balance Results

A district-wide water balance combining individual inflows and outflows into general categories is shown in Figure 3.8 for the water year and for the April to September primary irrigation season. In each figure, average volumes are presented for each inflow and outflow category, as well as average volumes expressed in acre-feet per acre. Average monthly inflows to and outflows from BWGWD are further summarized in Figures 3.9 and 3.10, respectively.

Detailed annual water balance results for the distribution and drainage system are summarized in Table 3.13. Detailed annual water balance results for the farmed lands are summarized in Table 3.14. In each table, performance indicators discussed in the following section are provided.

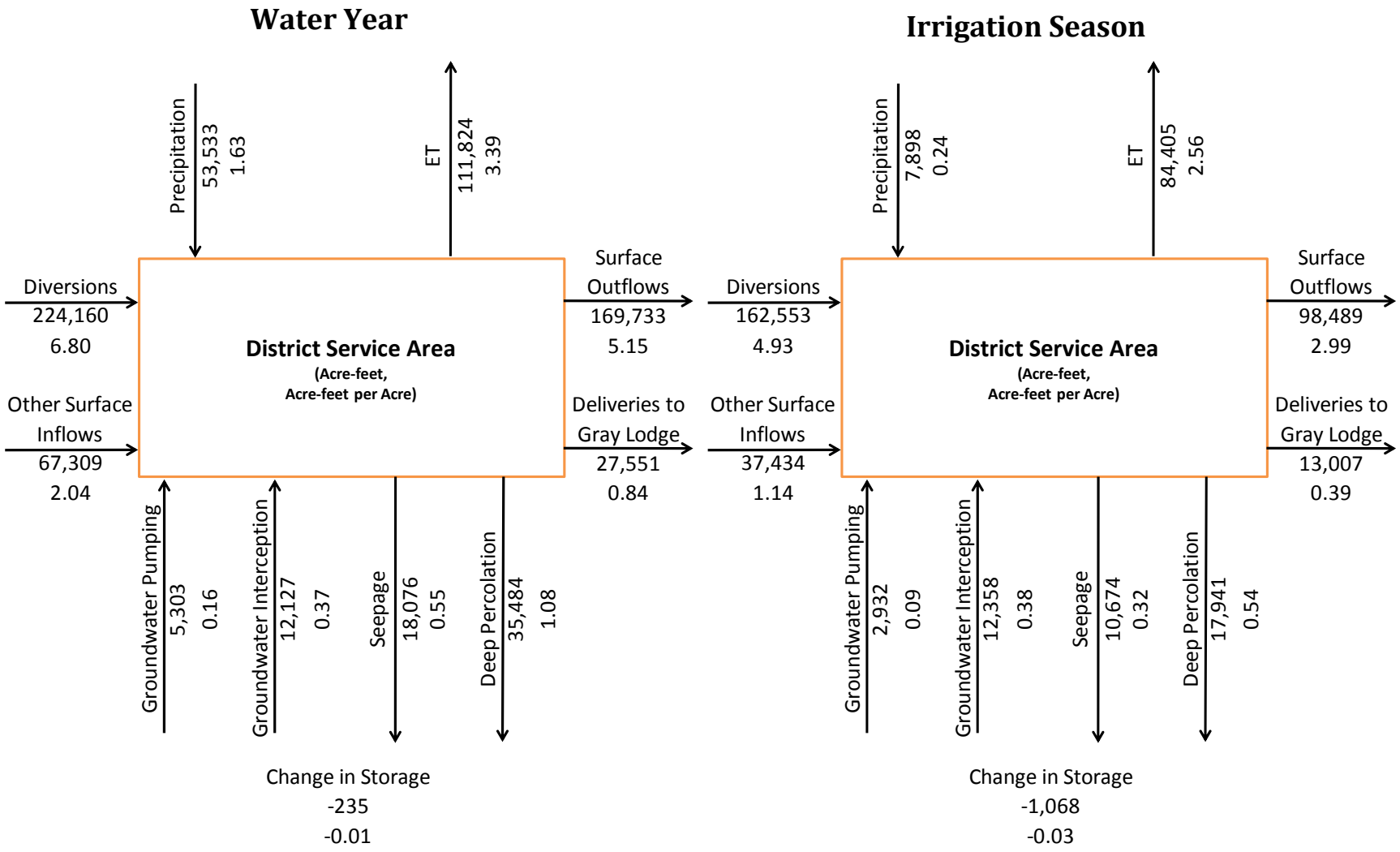

Figure 3.8. District Water Balance 1999-2014.

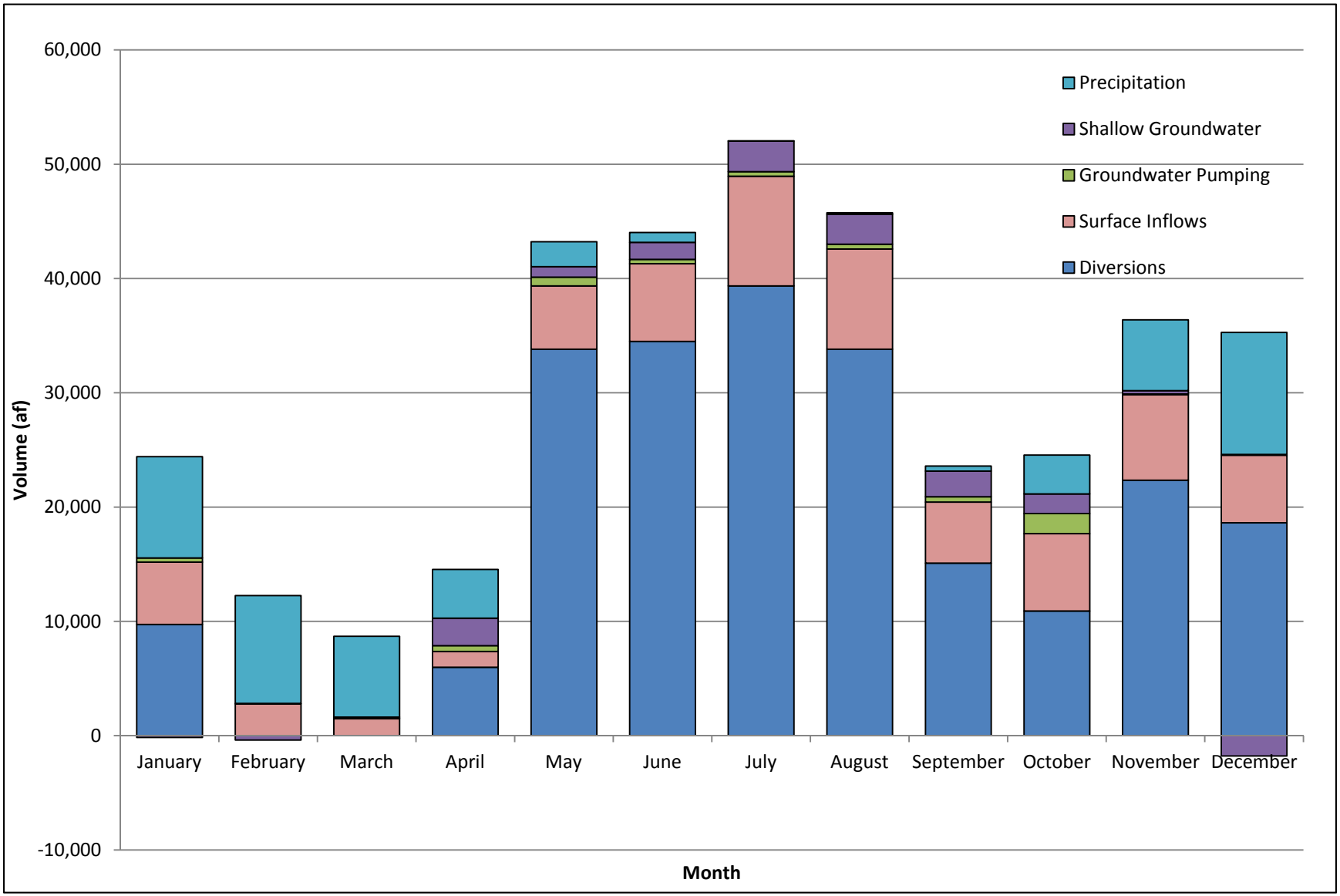

Figure 3.9. Average Monthly Inflows, 1999-2014.

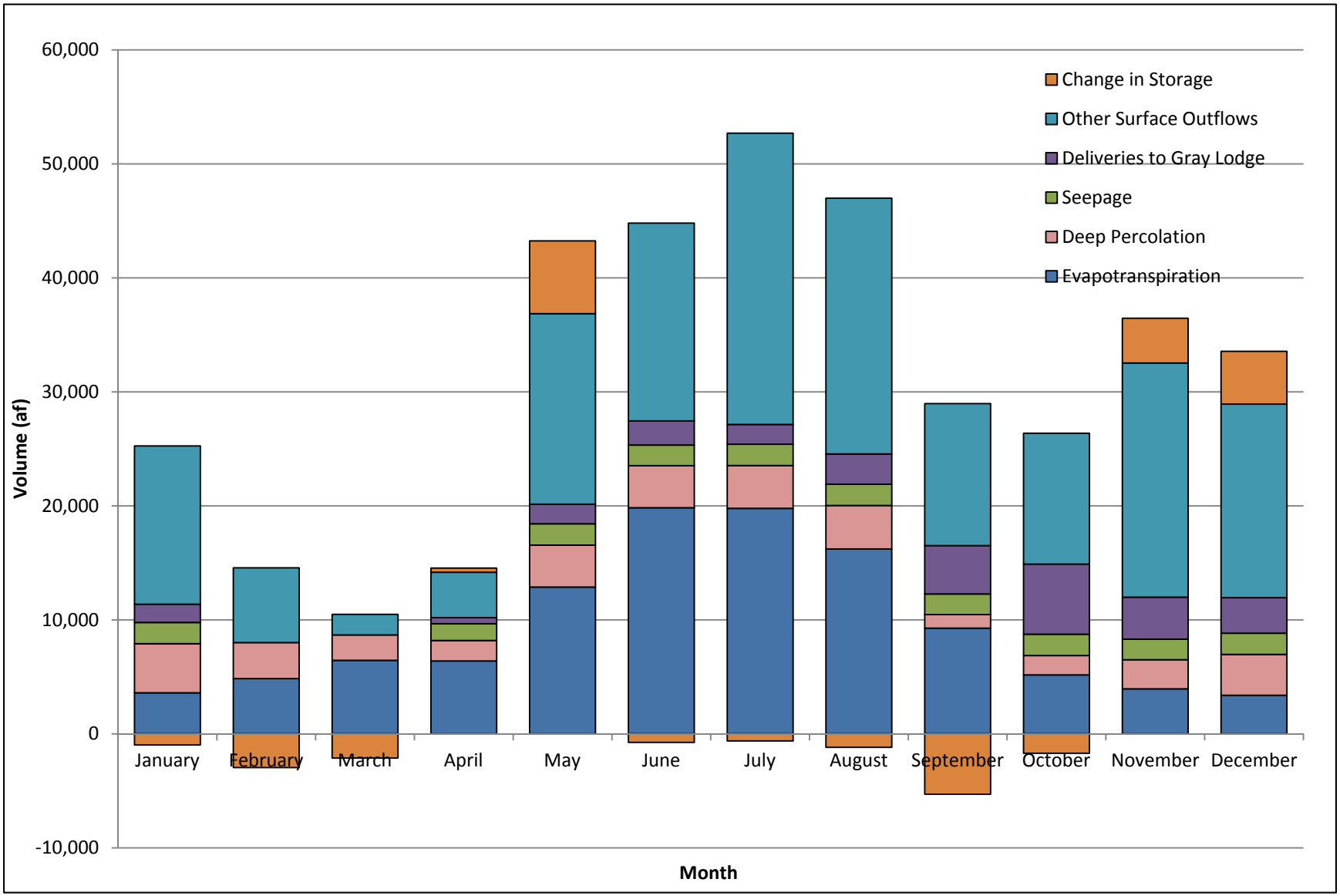

Figure 3.10. Average Monthly Outflows and Change in Storage, 1999-2014.

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Table 3.13. Distribution and Drainage System Annual Water Balance Results, 1999-2014.

	Inflows (af)										Outflows (af)						Performance Indicators	
Water Year	Main Canal Diversion	Branch A Diversion	Sutter-Butte Canal Diversions	Lateral 8 Diversion	RD833 Drains	Drains from BWD	Precipi-tation	Shallow Ground-water Interception	Runoff of Precipi-tation	Tailwater	Deliveries	Deliveries to Gray Lodge via Schwind, Cassady, and Rising River Laterals	Evapo-ration	Riparian ET	Seepage	Boundary Outflows	Delivery Fraction	Water Management Fraction
1999	195,249	4,866	7,849	5,908	40,445	16,303	354	9,095	15,236	57,142	163,264	25,744	1,034	204	18,414	143,787	0.88	0.996
2000	195,377	5,323	8,820	6,039	44,807	20,362	466	9,095	27,449	59,910	171,172	26,603	1,104	210	18,414	160,146	0.92	0.997
2001	193,952	4,239	8,830	6,209	41,087	19,138	363	9,095	17,595	60,982	174,234	27,078	1,123	217	18,414	140,425	0.94	0.996
2002	194,128	4,725	13,687	6,154	41,821	27,621	431	9,095	24,400	61,324	175,210	29,895	1,114	215	18,414	158,538	0.94	0.997
2003	183,429	2,757	18,355	5,940	44,130	29,966	508	9,095	29,242	55,838	159,538	28,134	1,067	208	18,414	171,900	0.89	0.997
2004	223,659	6,308	18,482	6,675	55,996	22,866	415	9,095	27,056	54,228	154,938	25,909	1,098	216	18,414	224,205	0.71	0.997
2005	199,758	4,823	16,069	5,997	54,208	18,570	499	9,095	25,456	53,367	152,478	35,066	999	197	18,414	180,688	0.83	0.997
2006	207,461	5,817	24,524	7,784	56,719	25,600	605	9,095	38,175	51,673	147,637	33,372	971	196	16,609	228,668	0.74	0.997
2007	213,616	5,773	22,452	9,119	41,337	20,906	260	9,095	11,330	66,565	190,186	19,664	1,093	229	18,414	170,866	0.84	0.997
2008	208,930	6,028	23,217	8,523	41,484	21,548	330	9,095	18,757	65,701	187,717	29,495	1,077	226	18,414	166,685	0.88	0.997
2009	182,292	5,037	20,577	7,187	40,494	24,548	324	9,095	16,637	60,743	173,550	29,864	1,004	211	18,414	143,891	0.95	0.997
2010	178,396	5,228	18,683	8,047	42,866	25,941	455	9,095	21,840	49,851	142,432	28,838	919	195	16,609	171,409	0.81	0.997
2011	191,680	5,237	21,460	8,599	53,718	27,057	618	9,095	35,111	48,349	138,140	25,474	886	188	18,414	217,822	0.72	0.997
2012	193,081	4,494	23,220	8,933	44,746	19,735	366	9,095	13,699	50,708	144,881	26,209	966	210	16,609	179,203	0.74	0.997
2013	190,968	4,917	24,024	7,750	37,728	20,203	272	9,095	10,485	60,296	172,273	22,813	1,121	219	18,414	150,899	0.86	0.996
2014	152,763	3,879	16,996	6,252	34,492	20,507	160	9,095	4,544	51,508	147,165	26,656	1,141	222	18,414	106,598	0.97	0.995
Minimum	152,763	2,757	7,849	5,908	34,492	16,303	160	9,095	4,544	48,349	138,140	19,664	886	188	16,609	106,598	0.71	0.995
Maximum	223,659	6,308	24,524	9,119	56,719	29,966	618	9,095	38,175	66,565	190,186	35,066	1,141	229	18,414	228,668	0.97	0.997
Average	194,046	4,966	17,953	7,195	44,755	22,554	402	9,095	21,063	56,762	162,176	27,551	1,045	210	18,076	169,733	0.87	0.997

Table 3.14. Farmed Lands Annual Water Balance Results, 1999-2014.

	Inflows (af)				Outflows (af)							Performance Indicators		
Water Year	Deliveries	Precipitation	Shallow Groundwater Interception	Groundwater Pumping	Crop ETaw	Crop ETpr	Deep Percolation of Applied Water	Deep Percolation of Precipitation	Runoff of Precipitation	Tailwater	Change in Storage (af)	Deliveries (af/ac)	Surface Water Supply Fraction	Crop Consumptive Use Fraction
1999	163,264	46,952	3,032	4,098	87,530	24,179	27,411	8,287	15,236	57,142	-2,439	6.06	0.98	0.52
2000	171,172	61,696	3,032	4,532	92,370	23,114	29,119	8,961	27,449	59,910	-492	6.42	0.97	0.53
2001	174,234	47,905	3,032	3,929	93,909	22,038	28,298	6,692	17,595	60,982	-414	6.73	0.98	0.53
2002	175,210	57,041	3,032	2,468	93,404	22,231	29,480	9,276	24,400	61,324	-2,364	6.77	0.99	0.53
2003	159,538	67,218	3,032	6,051	84,286	25,522	27,173	9,877	29,242	55,838	3,901	6.10	0.96	0.51
2004	154,938	54,873	3,032	7,256	89,328	18,179	28,201	8,840	27,056	54,228	-5,733	6.03	0.96	0.55
2005	152,478	66,062	3,032	6,788	78,649	27,335	27,407	10,011	25,456	53,367	6,134	5.81	0.96	0.49
2006	147,637	80,113	3,032	6,886	79,793	25,468	29,430	14,037	38,175	51,673	-908	5.71	0.96	0.52
2007	190,186	34,376	3,032	5,416	104,843	19,052	28,477	2,716	11,330	66,565	28	7.37	0.97	0.54
2008	187,717	43,627	3,032	5,888	103,552	19,080	30,149	5,814	18,757	65,701	-2,790	7.05	0.97	0.53
2009	173,550	42,846	3,032	5,914	95,250	19,415	29,115	4,176	16,637	60,743	7	6.61	0.97	0.53
2010	142,432	60,135	3,032	5,034	73,000	25,924	25,881	9,694	21,840	49,851	4,442	6.21	0.97	0.50
2011	138,140	81,732	3,032	4,437	74,505	29,286	27,285	14,279	35,111	48,349	-1,474	5.32	0.97	0.52
2012	144,881	48,454	3,032	4,093	77,644	27,144	23,789	7,167	13,699	50,708	310	6.43	0.97	0.52
2013	172,273	35,994	3,032	5,218	97,336	18,389	26,936	4,674	10,485	60,296	-1,599	6.59	0.97	0.55
2014	147,165	21,076	3,032	6,837	82,890	14,452	23,460	1,629	4,544	51,508	-374	7.24	0.96	0.54
Minimum	138,140	21,076	3,032	2,468	73,000	14,452	23,460	1,629	4,544	48,349	-5,733	5.32	0.96	0.49
Maximum	190,186	81,732	3,032	7,256	104,843	29,286	30,149	14,279	38,175	66,565	6,134	7.37	0.99	0.55
Average	162,176	53,131	3,032	5,303	88,018	22,550	27,601	7,883	21,063	56,762	-235	6.40	0.97	0.53

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Characterization of Water Management and Performance

District

Monthly inflow and outflow patterns provide insight into water management at the district-scale, which is heavily influenced by water management for rice. The observed monthly patterns likely differ from individual fields, and reflect the full population of fields in the district.

Diversions begin in April or May and continue at relatively steady levels through August, decreasing in September as fields are drained for harvest. In October and November diversions again increase and remain steady through December to flood fields for rice straw decomposition and habitat. Diversions cease in mid-January in preparation for the next year's crop. Surface inflows from drains in RID and BWD tend to follow a similar pattern to diversions, as they result largely from upstream rice irrigation, demonstrating the "cascading" characteristic of irrigation in the region, where return flows from upstream water users are available for downstream agricultural and environmental uses.

Monthly ET generally follows the pattern of ET_o, increasing in the spring and summer as temperatures and available solar radiation increase and decreasing in the winter. Actual ET rates are relatively similar to reference values due to the availability of adequate surface water supplies to support crop growth and relatively moist conditions throughout the growing season. Deep percolation and seepage are relatively constant over time due to the use of available surface water during the majority of the year, with deep percolation increasing somewhat in the winter as a result of precipitation and decreasing prior to planting and following harvest as a result of dry conditions. Surface outflows follow the general pattern of diversions, increasing during irrigation and winter flooding as a result of both irrigation and precipitation processes.

The monthly change in storage reflects rice growing and winter flooding as well, with water going into storage in April and May, remaining relatively constant in June and July, and coming out of storage as fields are drained in August and September. Storage then increases again October through December due to winter flooding and decreases in January through March in preparation for planting.

On a water year basis, substantial recharge of the groundwater system occurs as a result of the use of surface water within BWGWD. It is estimated that approximately 36,000 af of groundwater recharge net of groundwater pumping and shallow groundwater interception occur annually within the district. Net recharge is somewhat limited due to relatively shallow groundwater conditions in BWGWD resulting in part from historical use of surface water and limited pumping. Approximately 12,000 af of shallow groundwater interception occurs annually. Groundwater interception supports the growth of native vegetation and provides base flow for streams and drains.

Comparing total inflows to BWGWD to total outflows to meet consumptive irrigation demands plus recoverable return flows available for use by others or the environment, a Water Management

Fraction (WMF) may be calculated[9]. This indicator describes the amount of the total water supply not lost irrecoverably to evaporation from the canal and drain system (Equation 3.2).

$$Water\ Management\ Fraction = \frac{Evapotranspiration + Return\ Flows}{Inflows} \qquad [3.2]$$

Over the period from 1999 to 2014, the WMF was 0.997, indicating that essentially all available water supply is used to meet irrigation demands or is recoverable for downstream surface water and groundwater uses.

Distribution and Drainage System

Inflows to the distribution and drainage system in the BWGWD service area include diversions from the Thermalito Afterbay via the Main Canal, Branch A Canal, Lateral 8 diversions, and other deliveries from the Sutter Butte Canal; precipitation falling directly into canals and drains; inflows from drains in RID and BWD; runoff of precipitation from farmed lands; shallow groundwater interception; and tailwater inflows from farmed lands. Outflows include deliveries; surface outflows through the Hamilton Drain, RD833 drains, Snake Creek, and other drains; seepage; evaporation; and riparian ET.

The objective of BWGWD operations is to meet the irrigation and environmental water demands of its customers. The water balance results indicate several characteristics of water management by BWGWD and its customers. Comparing total deliveries to meet irrigation demand to diversions provides a measure of the effectiveness of system operation. A Delivery Fraction (DF), representing the ratio of deliveries to diversions may be calculated to provide an indicator of distribution and drainage system performance (Equation 3.3)[10].

$$Delivery\ Fraction = Deliveries/Diversions \qquad [3.3]$$

The DF ranged from 0.71 to 0.97 between 1999 and 2014 with an overall average of 0.87. DF values increase as a result of limiting operational spillage and through recovery and reuse of available water in the system by BWGWD and individual water users.

Farmed Lands

Inflows to the farmed lands include deliveries[11], groundwater pumping from private wells, and precipitation. Outflows include ET, tailwater, runoff of precipitation, and deep percolation. Additionally, as discussed previously, appreciable changes in stored water in the surface layer occur within the district as a result of rice production and winter flooding.

[9] The WMF is based on methodologies to quantify the efficiency of agricultural water use developed by DWR (DWR 2012b) and has been broadened to include all beneficial ET as well as all water supplies.
[10] Although the surface water supply includes sources other than diversions (e.g., precipitation inflows), the DF is calculated to include only diversions as this is the portion of surface water supply directly managed by BWGWD.
[11] As described previously, deliveries include direct deliveries by BWGWD and reuse by individual water users.

The objective of irrigation in BWGWD is to meet crop and environmental water demands in the most effective and efficient manner practical. Like the distribution and drainage system water balance, the farmed lands water balance provides insight into water management by BWGWD and growers.

Comparing total surface water supply (other than precipitation falling on farmed lands) to total irrigation supply including groundwater pumping, a surface water supply fraction (SWSF) may be calculated as an indicator of the relative amount of the total irrigation supply derived from surface water (Equation 3.4).

$$Surface\ Water\ Supply\ Fraction = Deliveries\ /\ (Deliveries + Groundwater\ Pumping) \qquad [3.4]$$

The SWSF was approximately 0.97 between 1999 and 2042, demonstrating the reliability of and reliance on surface water supplies within BWGWD. In the event of reduced surface water allocations due to surface water shortages, private groundwater pumping can be increased to some extent to minimize lost production, resulting in decreased SWSF for those years. It is estimated that the SWSF in the shortage years of 1991 and 1992 was approximately 0.91, indicating that even in years of reduced supply, surface water is the primary water source to meet demands.

Comparing crop ET_{aw} to total irrigation supplies, a crop consumptive use fraction (CCUF) may be calculated as an indicator of the relative amount of applied irrigation water consumed to grow the crop (Equation 3.5) (DWR 2012b).

$$\begin{aligned} &Crop\ Consumptive\ Use\ Fraction \\ &\qquad = Crop\ ET\ of\ Applied\ Water\ /\ (Deliveries + Groundwater\ Pumping) \end{aligned} \qquad [3.5]$$

Between 1999 and 2014, the CCUF ranged from 0.49 to 0.55 with an overall average of 0.53. These CCUF values are calculated at the field scale and thus are not reflective of water reuse within the district. Based on estimated reuse of approximately 30,000 af of surface water within the district annually, the average CCUF at the district scale is estimated to be 0.63[12].

3.8 Climate Change

Climate change has the potential to directly impact surface water resources in the Feather River region and to indirectly impact groundwater resources. Due to the similarity in the nature of diversion agreements with the State among the primary water suppliers relying on the Feather River and due to similarity in cropping, climate, soils, and other factors, potential effects of climate change, impacts on water management, and actions by individual suppliers or through regional coordination to help mitigate future impacts are described for the region as a whole in Volume I, Section 5 of this regional AWMP. In particular, the following are discussed:

- Potential effects of climate change within the region;

[12] Estimated as annual ET_{aw}/(deliveries + groundwater pumping – district reuse*DF – private reuse).

- Resulting potential impacts on water resources including water supply, water demand, water quality, and flood control;
- Ongoing and potential future actions to help mitigate future impacts; and
- Additional resources regarding water resources planning to address climate change.

3.9 Efficient Water Management Practices and Water Use Efficiency

3.9.1 Efficient Water Management Practices

BWGWD seeks to efficiently manage available water supplies to meet water management objectives, considering operational and financial constraints. BWGWD implements technically feasible efficient water management practices (EWMPs) described in the California Water code (CWC §10608.48) at locally cost-effective levels. Existing and planned water management activities related to each of the EWMPs are summarized in Table 3.15. Water use efficiency improvements achieved through these activities may include increased local, regional, and statewide water supplies and water supply reliability; increased local flexibility; increased in-stream flow; improved water quality; and improved energy efficiency.

Notable water management actions that BWGWD has implemented include the following:

- Implementation of a delivery measurement program and adoption of a water rate based in part on the volume of water delivered to comply with the requirements of the CWC and to support improved farm water management;
- Provision of flexible deliveries for the range of crops grown and irrigation methods employed to meet customer demands;
- Support of on-farm physical and management improvements in coordination with available programs;
- Implementation of a SCADA system for real-time monitoring of key district inflow and outflow sites;
- Modernization of structures in main canal and primary laterals through the Gray Lodge water supply project to increase the capacity, flexibility, and steadiness of the distribution system while reducing seepage;
- Recovery of drainwater at six recently inspected and rebuilt pumping locations;
- Implementation of frequent measurement of spills and boundary outflows to support improved operations and farm water management;
- Evaluation of opportunities to further improve service through automation of control structures and automation of and flow measurement for drainwater recovery pumps; and
- Ongoing coordination with DWR operations and other water management entities to evaluate and improve policies to allow for more flexible deliveries and storage.

As part of this plan, reconnaissance level cost estimates have been prepared for potential future water management improvements identified during field inspections and consultations with BWGWD staff. Additionally, potential benefits of the improvements have been estimated. These

improvements could be implemented over time as determined to be locally cost effective. Alternatively, these projects could be implemented to meet regional and statewide water management objectives. The evaluation of potential water management improvements is included as Attachment 3.10.4. Additionally, opportunities to improve the joint facilities used to convey water from the afterbay to BWGWD have been evaluated and are described in Section 10.1.

Implementation of improvements must consider the nature of water management in the region, whereby water not consumed is available for reuse by downstream water users and the environment. At this time, there is no incentive for the district to implement projects that are not locally cost effective but would result in conserved water remaining in storage. To the extent that such water can be released to increase overall water supplies or to meet timing and water quality objectives, these benefits are realized regionally or statewide by other water users such as State Water Project contractors, providing no direct benefit to the district.

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Table 3.15. EWMP Implementation Status.

Water Code Reference No.	EWMP	Implementation Status	Implemented Activities	Planned Activities
Critical (Mandatory) Efficient Water Management Practices				
10608.48.b(1)	Measure the volume of water delivered to customers with sufficient accuracy to comply with subdivision (a) of Section 531.10 and to implement paragraph (2).	Being Implemented	• Evaluated customer delivery measurement options. • Selected customer delivery measurement program (CDMP) certified to satisfy requirements of the Water Code and California Code of Regulations. • Prepared corrective action plan. • Implementing certified CDMP as funding allows. Approximately 100 turnouts were improved prior to the 2015 irrigation season for compliance with new delivery measurement regulations. An additional 150 to 200 turnout improvements are planned prior to the 2016 irrigation season. Turnouts must meet district standards in regards to quality and uniformity.	• Continue implementation of customer delivery measurement program.
10608.48.b(2)	Adopt a pricing structure for water customers based at least in part on quantity delivered.	Being Implemented	• Developed volumetric delivery accounting and reporting system with billing capabilities. • Completed Proposition 218 process and adopted a rate structure based in part on the volume of water delivered.	• Implement updated rate based in part on quantity delivered.
Additional (Conditional) Efficient Water Management Practices				
10608.48.c(1)	Facilitate alternative land use for lands with exceptionally high water duties or whose irrigation contributes to significant problems, including drainage.	Not Technically Feasible	Lands with exceptionally high water duties or whose irrigation contributes to significant problems are not found within BWGWD. Furthermore, BWGWD's rules and regulations prohibit wasteful use of water, preventing exceptional water duties or significant problems from occurring. Water applied but not consumed to produce crops provides beneficial groundwater recharge or is available for downstream uses.	
10608.48.c(2)	Facilitate use of available recycled water that otherwise would not be used beneficially, meets all health and safety criteria, and does not harm crops or soils	Not Technically Feasible	• There is no available water from municipal or industrial uses that meets all health and safety criteria within the service area.	• BWGWD is willing to consider opportunities for use of available recycled water if it meets all health and safety criteria.
10608.48.c(3)	Facilitate financing of capital improvements for on-farm irrigation systems	Being Implemented	• BWGWD has improved turnouts and toe drains along the main canal and primary laterals as part of the Gray Lodge Wildlife Area Water Supply Project (GLWAWSP). Turnouts must meet district standards in regards to quality and uniformity. • BWGWD has provided improved delivery infrastructure as part of its delivery measurement program. • BWGWD is available to provide technical support for the development of NRCS conservation plans by its customers.	• Continue improvements to turnouts and toe drains as part of GLWAWSP. • Continue delivery measurement improvements. • Continue to coordinate with customers regarding NRCS conservation planning.
10608.48.c(4)	Implement an incentive pricing structure that promotes one or more of the following goals: (A) More efficient water use at farm level, (B) Conjunctive use of groundwater, (C) Appropriate increase of groundwater recharge, (D) Reduction in problem drainage, (E) Improved management of environmental resources, (F) Effective management of all water sources throughout the year by adjusting seasonal pricing structures based on current conditions.	Being Implemented	• BWGWD promotes goal A through adoption of a water rate based in part on the volume of water delivered and as appropriate through a no spill policy for tailwater, which includes notification and disciplinary steps. • BWGWD water rates promote goals B and C by encouraging the use of available surface water supplies, which provides beneficial groundwater recharge through deep percolation. Groundwater is then available in years of surface water shortage while maintaining long term sustainability of the groundwater system. • BWGWD water rates promote goal E by providing a reliable, affordable source of water to maintain both public and private waterfowl habitat and wetlands, including winter flooding of rice fields. In addition to other species, wetlands within the district provide habitat for the Giant Garter Snake, a federally threatened species. • BWGWD promotes goal E by providing district water at an affordable rate and by conveying CVPIA water to the Gray Lodge Wildlife Area through its distribution system.	• Continue to promote goals A, B, C, and E through current water rates. • Implement volumetric pricing to further promote goal A.

Water Code Reference No.	EWMP	Implementation Status	Implemented Activities	Planned Activities
10608.48.c(5)	Expand line or pipe distribution systems, and construct regulatory reservoirs to increase distribution system flexibility and capacity, decrease maintenance and reduce seepage	Being Implemented	• Construction of compacted inner prisms in the main canal and primary laterals currently being implemented as part of the GLWAWSP has substantially reduced horizontal seepage and increased capacity in completed sections. Compaction of existing clay soils is more cost effective than concrete lining or pipeline conversion. • Water level control structures installed in the main canal and primary laterals as part of the GLWAWSP has increased distribution system flexibility and capacity. • Laterals traversing developed areas have been converted to pipelines to reduce seepage and increase public safety. • Flow measurement has been implemented at key lateral headings to improve distribution system flexibility.	• Continue implementation of GLWAWSP. • Continue pipeline conversion, as appropriate.
10608.48.c(6)	Increase flexibility in water ordering by, and delivery to, water customers within operational limits	Being Implemented	• BWGWD provides a high degree of flexibility to customers by providing orders with 24-hour notice, in most cases. • Modernization of structures as part of the GLWAWSP enhances flexibility in water ordering by and delivery to customers. • Improvements underway through the CDMP provide more precise deliveries to meet customer demands and allow for more flexible ordering. • BWGWD has evaluated opportunities and will seek grant funding to further improve service through automation of additional control structures and implementation of automation and flow measurement on drainwater recovery pumps. • BWGWD has evaluated opportunities to modernize and automate Joint Water District facilities, to decrease fluctuations in deliveries to BWGWD and allow for more precise deliveries to meet customer demands. • Flow measurement has been implemented at key lateral headings to improve distribution system flexibility. • Real time water level monitoring implemented at two key locations on the primary distribution system allows for increase flexibility and includes automatic alarms to alert operators of potential canal overtopping.	• Continue implementation of GLWAWSP. • Continue implementation of CDMP. • Explore options and proceed with additional modernization, automation, and flow measurement improvements, contingent on availability of funding and project prioritization.
10608.48.c(7)	Construct and operate supplier spill and tailwater recovery systems	Being Implemented	• Drainwater recovery into the distribution system for reuse is currently accomplished via pumping in six locations within BWGWD. These pumps were recently inspected and rebuilt. BWGWD will seek grant funding for implementation of automation and flow measurement on drainwater recovery pumps. • Modernization of structures and other improvements underway as part of GLWAWSP and CDMP allow for operational and farm water management improvements that result in reduced spillage and tailwater. • Implementing frequent measurement of spills and boundary outflows supports spillage reduction. • BWGWD has evaluated opportunities and will seek grant funding to further improve service through automation of additional control structures. • Real time water level monitoring implemented at two key locations on the primary distribution system allows for increase flexibility and includes automatic alarms to alert operators of potential canal overtopping.	• Continue drainwater recovery into the distribution system for reuse. Continue to regularly inspect and rebuild drainwater recovery pumps as appropriate. • Continue implementation of GLWAWSP and CDMP. • Continue outflow monitoring. • Explore options and proceed with automation and flow measurement improvements, contingent on availability of funding and project prioritization.

Water Code Reference No.	EWMP	Implementation Status	Implemented Activities	Planned Activities
10608.48.c(8)	Increase planned conjunctive use of surface water and groundwater within the supplier service area	Being Implemented	• An adequate amount of surface water is available for irrigation in most years. During shortage years, groundwater is used conjunctively with reduced surface water supplies through private pumping to meet demand. • Shortage allocation policies are designed to facilitate the conjunctive use of groundwater in surface water shortage years. • In 2015, BWGWD approved installation of one groundwater well to augment surface water supplies during shortage years. • The district is actively involved in implementation of the Sustainable Groundwater Management Act (SGMA) as a Groundwater Sustainability Agency (GSA) and works collaboratively with other interested parties to implement the Act.	• Continue usage of surface water when available and conjunctive use of surface water and groundwater during periods of shortage to meet demand. • Proceed with development and construction of a district groundwater well, contingent on available funding and project prioritization. • Continue implementation of SGMA as a GSA.
10608.48.c(9)	Automate canal control structures	Being Implemented	• Modernization of structures as part of the GLWAWSP provides automatic level control through construction of long-crested weirs. • BWGWD evaluated opportunities and will seek grant funding to further improve service through further automation of control structures and implementation of automation and flow measurement on drainwater recovery pumps.	• Continue implementation of GLWAWSP. • Explore options and proceed with automation and flow measurement improvements, contingent on the availability of funding and project prioritization.
10608.48.c(10)	Facilitate or promote customer pump testing and evaluation	Being Implemented	• BWGWD requires flowmeters on private groundwater pumps used to pump water into the distribution system during shortage years, which enables evaluation of pump performance. Several flowmeters were installed in 2015 in response to increased reliance on groundwater as a result of curtailment of surface water supplies. • Implementation of the CDMP requires flowmeters on pump deliveries within BWGWD, which enables evaluation of pump performance.	• Continue requiring flowmeters on private groundwater pumps used to pump water into the distribution system during shortage years. • Continue implementation of the CDMP.
10608.48.c(11)	Designate a water conservation coordinator who will develop and implement the water management plan and prepare progress report.	Being Implemented	• The General Manager serves as water conservation coordinator and is responsible for implementing the AWMP and providing regular reports to the Board of Directors on water management.	• GM will continue to serve as water conservation coordinator.
10608.48.c(12)	Provide for the availability of water management services to water users.	Being Implemented	• BWGWD monitors deliveries and tailwater on an on-going basis to support water management by water users. • BWGWD supports improved water management as appropriate through a no spill policy for tailwater, which includes notification and disciplinary steps.	• Continue monitoring deliveries and tailwater.
10608.48.c(13)	Evaluate the policies of agencies that provide the supplier with water to identify the potential for institutional changes to allow more flexible water deliveries and storage.	Being Implemented	• BWGWD conducts ongoing interactions with DWR SWP operations and with USBR MPR operations to facilitate CVPIA deliveries to GLWA. • BWGWD is a voluntary participant in ACWA and NCWA. • BWGWD is a participant in the Sacramento Valley IRWMP. • BWGWD is a voluntary participant in FRRAWMP. • BWGWD is a voluntary partner in USGS Endangered Species studies and in improving and managing wildlife habitat with NGOs. • GM serves on the Butte County Water Commission technical advisory committee. • BWGWD participates in Joint District and other Feather diverter interactions with SWP operations.	• Continue interactions with DWR SWP operations. • Continue to evaluate policies of agencies that provide BWGWD with water. • Continue to participate in Endangered Species and environmental studies. • Continue to participate in local, regional, and statewide committees and associations. • Continue to participate in local and regional planning initiatives.
10608.48.c(14)	Evaluate and improve the efficiencies of the supplier's pumps.	Being Implemented	• BWGWD inspects, tests, and rebuilds pumps used for drainwater recovery on an ongoing basis as needed. • BWGWD evaluated hydropower generation at the Main Canal heading and determined that it is not economically feasible at this time.	• Continue to regularly inspect, test, and rebuild drainwater recovery pumps as appropriate. • Explore options and proceed with hydropower generation project, contingent on economic feasibility, the availability of funding, and project prioritization.

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3.9.2 Evaluation of Water Use Efficiency Improvements

CWC §10608.48(d) requires that AWMPs include:

> *… a report on which efficient water management practices have been implemented and are planned to be implemented, an estimate of the water use efficiency improvements that have occurred since the last report, and an estimate of the water use efficiency improvements estimated to occur five and 10 years in the future.*

A description of EWMPs that have been implemented by BWGWD has been provided previously in Section 3.9.1. This section provides an evaluation of EWMP implementation and an estimate of water use efficiency (WUE) improvements that have occurred in the past and are expected to occur in the future.

The value of evaluating water use efficiency (WUE) improvements (and EWMP implementation in general) from BWGWD's perspective is to identify what the benefits of EWMP implementation are and to identify those additional actions that hold the potential to support and advance the district's water management objectives. BWGWD's water management objectives include the long term reliability, quality, and affordability of local surface water and groundwater supplies and providing the best service practical to water users it supplies. To that end, BWGWD has taken action to develop and maintain reliable surface water and groundwater supplies, to prevent or reduce losses from the distribution system in order to increase operational efficiency, to promote the efficient use of water at the farm level, and to meet changing environmental and other demands that affect the flexibility with which the district can divert and deliver water. BWGWD's water management activities are consistent with these objectives and have resulted in local and statewide benefits.

First and foremost among the issues that must be considered in any evaluation of the benefits of EWMP implementation and resulting WUE improvements is how water management actions affect the water balance (Davenport and Hagan, 1982; Keller, et al., 1996; Burt, et al., 2008; Clemmens, et al., 2008; Canessa, et al., 2011). Accordingly, any evaluation of EWMP implementation and WUE improvements for BWGWD must consider how water balance changes relate to the district's water management objectives. For example, flows to deep percolation and seepage that could be considered losses in some settings are critical to maintain the long-term sustainability of the underlying groundwater basin. Reductions in these flows resulting from EWMP implementation could be considered WUE improvements at the farm or district scale, but have the consequential effect of diminishing recharge of the underlying groundwater system. Other flows that could be considered losses at the farm or district scale such as spillage and tailwater are also recoverable. For example, spillage from the BWGWD distribution and drainage systems is available for beneficial use by downgradient water users. The only distribution and drainage system or on-farm losses that are not recoverable within the BWGWD service areas, the underlying groundwater basin, or the Feather River region as a whole are canal and drain water surface evaporation. These components represent a small portion of BWGWD's water supply (less than one percent as indicated in Table 3.13). An implication of this is that very little "new" water can be made available through water conservation in BWGWD's service area to increase the State's overall water supply;

however, there may be opportunities to change the timing and amount of water used to meet local, regional, or statewide objectives, as discussed in Volume I, Section 3 of this AWMP.

An important step in evaluating EWMP implementation and water use efficiency improvements is a comprehensive, quantitative, multi-year water balance (see Section 3.7). The quantitative understanding of water use enables identification of targeted flow paths for WUE improvements, along with improved understanding of the beneficial impacts and consequential effects of EWMP implementation at varying spatial and temporal scales. The water balance enables evaluation of potential changes in water use amounts and timing for any given change in water management.

Even where comprehensive, multi-year water balances have been developed, evaluating water balance impacts and WUE improvements is not a trivial task. Issues of spatial and temporal scale and relatively small changes in flow paths resulting from many water management improvements (relative to day to day and year to year variation in water diversions and use) coupled with inaccuracies inherent in even the best water measurement complicate the evaluation of water balance impacts. The implications of recoverable and irrecoverable losses at varying scales complicate the evaluation of WUE improvements, and consequential, potentially unintended effects must be considered.

As part of assembling this AWMP, BWGWD has identified the targeted flow paths associated with implementation of each EWMP, the water management benefits of each EWMP and the potential consequential effects of implementation. A brief discussion of the benefits associated with implementation of each EWMP is provided, along with a brief discussion of consequential effects that must be considered. A summary of targeted flow paths, impacts, and consequential effects associated with implementation of each EWMP by BWGWD is provided in Table 3.16.

Table 3.16. Summary of Targeted Flow Paths, Impacts, and Consequential Effects Associated with EWMP Implementation.

Water Code Reference No.	EWMP	Implementation Status	Targeted Flow Path(s)	Benefits	Consequential Effects	Notes (See End of Table)
10608.48.b (1)	Measure the volume of water delivered to customers with sufficient accuracy.	Being Implemented	Deliveries, Spillage, Tailwater, Diversions, Drainage Outflows	Delivery measurement can encourage efficient on-farm water use, dependent on pricing, and has the potential to lead to reduced deliveries. Reduced deliveries result in reduced diversions, which result in corresponding reductions in spillage and drainage outflows. Available water not diverted remains in storage and can improve local supply reliability or could potentially be available for transfer. Additionally, water quality benefits may occur through reduced tailwater outflow.	Increased on-farm water use efficiency results in reduced tailwater available for reuse by downstream water users. For crops other than rice, increased on-farm efficiency results in reduced beneficial recharge to the groundwater system through deep percolation.	1
10608.48.b (2)	Adopt a pricing structure based at least in part on quantity delivered.	Being Implemented	Deliveries, Spillage, Tailwater, Diversions, Drainage Outflows	Volumetric pricing may result in increased efficiency of on-farm water use, which has the potential to lead to reduced deliveries. Reduced deliveries result in reduced diversions, which result in corresponding reductions in spillage and drainage outflows. Available water not diverted remains in storage and can improve local supply reliability or could potentially be available for transfer. Additionally, water quality benefits may occur through reduced tailwater outflow.	Increased on-farm water use efficiency results in reduced tailwater available for reuse by downstream water users. For crops other than rice, increased on-farm efficiency results in reduced beneficial recharge to the groundwater system through deep percolation.	1
10608.48.c (1)	Facilitate alternative land use for lands with exceptionally high water duties or whose irrigation contributes to significant problems, including drainage.	Not Technically Feasible	Not Applicable	Not Applicable	Not Applicable	2
10608.48.c (2)	Facilitate use of available recycled water that otherwise would not be used beneficially, meets all health and safety criteria, and does not harm crops or soils.	Not Technically Feasible	Not Applicable	Not Applicable	Not Applicable	2
10608.48.c (3)	Facilitate financing of capital improvements for on-farm irrigation systems.	Being Implemented	Deliveries, Spillage, Tailwater, Diversions, Groundwater Pumping, Drainage Outflows	Providing technical support to available programs for assisting in on-farm improvements can result in reduced deliveries due to increased delivery efficiency and/or reduced tailwater and, in some cases, deep percolation. Reduced deliveries result in reduced diversions, which result in corresponding reductions in spillage and drainage outflows. Available water not diverted remains in storage and can improve local supply reliability or could potentially be available for transfer. Additionally, water quality benefits may occur through reduced tailwater outflow.	Increased on-farm water use efficiency results in reduced tailwater available for reuse by downstream water users. For crops other than rice, increased on-farm efficiency results in reduced beneficial recharge to the groundwater system through deep percolation. Reduced operational spillage, tailwater, and drainage outflows result in reduced water available downstream for beneficial use for agriculture or the environment.	1

Water Code Reference No.	EWMP	Implementation Status	Targeted Flow Path(s)	Benefits	Consequential Effects	Notes (See End of Table)
10608.48.c (4)	Implement an incentive pricing structure that promotes one or more of the following goals: (A) More efficient water use at farm level, (B) Conjunctive use of groundwater, (C) Appropriate increase of groundwater recharge, (D) Reduction in problem drainage, (E) Improved management of environmental resources, (F) Effective management of all water sources throughout the year by adjusting seasonal pricing structures based on current conditions.	Being Implemented	Varies	Volumetric pricing promotes goal (A), resulting in potential on-farm benefits as described for the volumetric pricing EWMP (10608.48.b(2)). Provision of surface water at lower rates than the cost of groundwater pumping incentivizes goals (B) and (C) and improves the reliability of regional water supplies while maintaining and enhancing ecosystems. Provision of water at affordable rates incentivizes goal (E) by offering a reasonably priced, reliable source of water to maintain both public and private waterfowl habitat and wetlands, including winter flooding of rice fields and Gray Lodge Wildlife Area.	Consequential effects of volumetric pricing are the same as described for the volumetric pricing EWMP (10608.48.b(2)).	1
10608.48.c (5)	Expand line or pipe distribution systems, and construct regulatory reservoirs to increase distribution system flexibility and capacity, decrease maintenance and reduce seepage.	Being Implemented	Deliveries, Spillage, Tailwater, Deep Percolation, Seepage, Diversions, Drainage Outflows	Reductions in losses such as seepage, operational spillage, and drainage outflows are being achieved through construction of compacted, minimal seepage embankments and water level control structures as part of the GLWAWSP. Regulating reservoirs provide improved consistency in deliveries, potentially providing a modest reduction in on-farm deliveries due to reduced tailwater and, in some cases, deep percolation and tailwater. Due to the proximity of the District's system to Thermalito Afterbay and use of drainwater recycling to achieve similar benefits to a regulating reservoir within the system, additional regulating storage would provide limited additional benefit. Water quality benefits may occur through reduced tailwater outflow.	Reduced seepage and deep percolation result in reduced beneficial recharge of the underlying groundwater system. Reduced operational spillage, tailwater, and drainage outflows result in reduced water available downstream for beneficial use for agriculture or the environment.	1
10608.48.c (6)	Increase flexibility in water ordering by, and delivery to, water customers within operational limits.	Being Implemented	Deliveries, Spillage, Tailwater, Diversions, Deep Percolation, Groundwater Pumping, Drainage Outflows	Flexible water ordering and deliveries result in reduced operational spillage, tailwater, and, in some cases, seepage and deep percolation. It can also result in a modest reduction in deliveries due to on-farm reductions in tailwater and deep percolation. System improvements result in greater operational efficiency and reductions in spillage. Additionally, water quality benefits may occur through reduced tailwater outflow. In aggregate, reduced losses (both on-farm and at the district level) can lead to reduced deliveries and reduced diversions. Available water not diverted remains in storage and can improve local supply reliability or could potentially be available for transfer.	Increased on-farm water use efficiency results in reduced tailwater available for reuse by downstream water users. For crops other than rice, increased on-farm efficiency results in reduced beneficial recharge to the groundwater system through deep percolation. Reduced operational spillage, tailwater, and drainage outflows result in reduced water available downstream for beneficial use for agriculture or the environment.	1

Water Code Reference No.	EWMP	Implementation Status	Targeted Flow Path(s)	Benefits	Consequential Effects	Notes (See End of Table)
10608.48.c (7)	Construct and operate supplier spill and tailwater recovery systems.	Being Implemented	Deliveries, Spillage, Tailwater, Diversions, Drainage Outflows	Reuse of operational spillage and tailwater results in decreased required diversions. Available water not diverted remains in storage and can improve local supply reliability or could potentially be available for transfer. Additionally, downstream water quality benefits may occur through reduced tailwater outflow.	Reduced operational spillage, tailwater, and drainage outflows result in reduced water available downstream for beneficial use for agriculture or the environment. Tailwater may be of diminished quality as compared to other available water supplies. Spillage and tailwater recovery using pumps requires the use of electricity or fuel as a component, increasing energy demand.	1
10608.48.c (8)	Increase planned conjunctive use of surface water and groundwater within the supplier service area.	Being Implemented	Diversions, Deliveries, Deep Percolation, Groundwater Pumping	Conjunctive management provides multiple benefits: • Maintain local, regional, and statewide water supply reliability • Enhance aquatic and wetlands ecosystems • Reduce energy requirements for irrigation	Not Significant	1
10608.48.c (9)	Automate canal control structures.	Being Implemented	Deliveries, Spillage, Tailwater, Diversions, Drainage Outflows	Automation results in reduced operational spillage and reduced deliveries due to increased delivery efficiency, which reduces on-farm tailwater and, in some cases, deep percolation. Reduced deliveries result in reduced diversions, which results in corresponding reductions in spillage and drainage outflows. Available water not diverted remains in storage and can improve local supply reliability or could potentially be available for transfer. Additionally, water quality benefits may occur through reduced tailwater outflow.	Increased on-farm water use efficiency results in reduced tailwater available for reuse by downstream water users. For crops other than rice, increased on-farm efficiency results in reduced beneficial recharge to the groundwater system through deep percolation. Reduced operational spillage, tailwater, and drainage outflows result in reduced water available downstream for beneficial use for agriculture or the environment.	1
10608.48.c (10)	Facilitate or promote customer pump testing and evaluation.	Being Implemented	None	Improved pumping efficiency by BWGWD's customers results in decreased energy demand and reduced pumping costs for customers. There are no direct benefits to BWGWD.	Not Significant	
10608.48.c (11)	Designate a water conservation coordinator who will develop and implement the water management plan and prepare progress report.	Being Implemented	Varies	See Comment	See Comment	3
10608.48.c (12)	Provide for the availability of water management services to water users.	Being Implemented	Deliveries, Spillage, Tailwater, Diversions, Groundwater Pumping, Drainage Outflows	Promoting available water management services can increase efficiency of on-farm water use, which has the potential of leading to reduced deliveries. Reduced deliveries result in reduced diversions, which result in corresponding reductions in spillage and drainage outflows. Available water not diverted remains in storage and can improve local supply reliability or could potentially be available for transfer. Additionally, water quality benefits may occur through reduced tailwater outflow.	Increased on-farm water use efficiency results in reduced tailwater available for reuse by downstream water users. For crops other than rice, increased on-farm efficiency results in reduced beneficial recharge to the groundwater system through deep percolation. Reduced operational spillage, tailwater, and drainage outflows result in reduced water available downstream for beneficial use for agriculture or the environment.	1
10608.48.c (13)	Evaluate the policies of agencies that provide the supplier with water to identify the potential for institutional changes to allow more flexible water deliveries and storage.	Being Implemented	Diversions	Increased flexibility and storage for the surface water supply could result in reductions in losses to operational spillage, tailwater, and drainage outflows. Additionally, water quality benefits may occur through reduced tailwater outflow.	Reduced operational spillage, tailwater, and drainage outflows result in reduced water available downstream for beneficial use for agriculture or the environment.	1

Water Code Reference No.	EWMP	Implementation Status	Targeted Flow Path(s)	Benefits	Consequential Effects	Notes (See End of Table)
10608.48.c (14)	Evaluate and improve the efficiencies of the supplier's pumps.	Being Implemented	None	Improved pumping efficiency of BWGWD's pumps and prioritizing repairs or replacement based on pump evaluations results in decreased energy demand and reduced pumping costs for BWGWD and increases pump reliability. There are no direct impacts to water balance flow paths.	Not Significant	

Notes:

1. BWGWD works to balance tradeoffs between incentivizing water conservation (both districtwide and on-farm) and maintaining long-term surface water and groundwater reliability.
2. Such conditions do not exist in BWGWD. As a result, it is not technically feasible to implement this EWMP.
3. Implementation of the AWMP by BWGWD's Water Conservation Coordinator and other staff as appropriate is the mechanism by which all EWMPs are implemented and targeted benefits are realized.

WUE definitions vary. For purposes of evaluating WUE improvements associated with EWMP implementation by BWGWD, specific WUE improvement categories or objectives have been identified that correspond to each EWMP. Potential WUE improvements include reduction of irrecoverable losses, increased local supply and supply reliability, increased local flexibility, increased in-stream flow, improved water quality, and improved energy efficiency. Definitions for each of the WUE improvement categories have been developed and are provided in Table 3.17. Note that the WUE improvement categories are not mutually exclusive in many cases. For example, reductions in irrecoverable losses could be used to increase local supply. The applicability of each EWMP to each WUE improvement category based on BWGWD's water management activities has been identified and is presented in Table 3.18.

Table 3.17. WUE Improvement Categories.

Water Use Efficiency Improvement Category	Definition
Reduce Irrecoverable Losses	Reduce losses that cannot be recovered and used by the water supplier or downgradient users (e.g. evaporation and flows to salt sinks).
Increase Local Supply (and Supply Reliability)	Reduce losses and/or increase storage locally to increase supply available to meet demands, including both near-term (within an irrigation season) and long-term (over more than one year).
Increase Local Flexibility	Improve the supplier's ability to divert, pump, convey, control, and deliver available water supplies to meet customer demands.
Increase In-Stream Flow	Increase flow in natural waterways to benefit fisheries or meet other environmental objectives.
Improve Water Quality	Increase the quality of targeted water bodies (i.e. streams, lakes, or aquifers).
Improve Energy Efficiency	Increase the efficiency of water supplier or customer pumps.

In order to more explicitly report an estimate of WUE improvements and an estimate of WUE improvements expected to occur five and ten years in the future, BWGWD has estimated the qualitative magnitude (expressed as None, Limited, Modest, or Substantial in order of increasing relative magnitude) for the targeted flow paths associated with each EWMP relative to the applicable WUE improvement categories identified in Table 3.18. Past WUE improvements are estimated relative to no historical implementation. WUE improvements relative to the time of the last plan are relative to 2014, the time when the plan was adopted. Future WUE improvements are estimated for five years in the future (2020) relative to 2015 and for ten years in the future (2025) relative to 2015. The result of this evaluation is provided in Table 3.19.

BWGWD will continue to seek out and implement water management actions that meet its overall water management objectives and result in WUE improvements. The continuing review of water management within BWGWD, coupled with exploration of innovative opportunities to improve water management will result in future management improvements by the district and resulting WUE improvements.

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Table 3.18. Applicability of EWMPs to WUE Improvement Categories.

Water Code Reference No.	EWMP	Implementation Status	Potential Water Use Efficiency Improvement Category					
			Reduce Irrecoverable Losses	Increase Local Supply	Increase Local Flexibility	Increase In-Stream Flow	Improve Water Quality	Improve Energy Efficiency [1]
10608.48.b (1)	Measure the volume of water delivered to customers with sufficient accuracy	Being Implemented		✓		✓	✓	✓
10608.48.b (2)	Adopt a pricing structure based at least in part on quantity delivered	Being Implemented		✓		✓	✓	
10608.48.c (1)	Facilitate alternative land use for lands with exceptionally high water duties or whose irrigation contributes to significant problems, including drainage.	Not Technically Feasible	Not Applicable to BWGWD					
10608.48.c (2)	Facilitate use of available recycled water that otherwise would not be used beneficially, meets all health and safety criteria, and does not harm crops or soils.	Not Technically Feasible	Not Applicable to BWGWD					
10608.48.c (3)	Facilitate financing of capital improvements for on-farm irrigation systems	Being Implemented		✓		✓	✓	
10608.48.c (4)	Implement an incentive pricing structure that promotes one or more of the following goals: (A) More efficient water use at farm level, (B) Conjunctive use of groundwater, (C) Appropriate increase of groundwater recharge, (D) Reduction in problem drainage, (E) Improved management of environmental resources, (F) Effective management of all water sources throughout the year by adjusting seasonal pricing structures based on current conditions.	Being Implemented		✓		✓	✓	
10608.48.c (5)	Expand line or pipe distribution systems, and construct regulatory reservoirs to increase distribution system flexibility and capacity, decrease maintenance and reduce seepage	Being Implemented		✓	✓	✓	✓	
10608.48.c (6)	Increase flexibility in water ordering by, and delivery to, water customers within operational limits	Being Implemented		✓	✓	✓	✓	
10608.48.c (7)	Construct and operate supplier spill and tailwater recovery systems	Being Implemented		✓	✓	✓	✓	
10608.48.c (8)	Increase planned conjunctive use of surface water and groundwater within the supplier service area	Being Implemented		✓				
10608.48.c (9)	Automate canal control structures	Being Implemented		✓	✓	✓	✓	
10608.48.c (10)	Facilitate or promote customer pump testing and evaluation	Being Implemented						✓
10608.48.c (11)	Designate a water conservation coordinator who will develop and implement the water management plan and prepare progress report.	Being Implemented	The activities of the Water Conservation Coordinator and other BWGWD staff to achieve WUE improvements through implementation of the AWMP are described individually by EWMP.					
10608.48.c (12)	Provide for the availability of water management services to water users.	Being Implemented		✓		✓	✓	✓
10608.48.c (13)	Evaluate the policies of agencies that provide the supplier with water to identify the potential for institutional changes to allow more flexible water deliveries and storage.	Being Implemented		✓	✓	✓	✓	
10608.48.c (14)	Evaluate and improve the efficiencies of the supplier's pumps.	Being Implemented						✓

1. Includes reducing energy demands.

Table 3.19. Relative Magnitude of Past and Future WUE Improvements by EWMP.

Water Code Reference No.	EWMP	Implementation Status	Marginal WUE Improvement[1,2]			
			Past		Future	
			Relative to No Historical Implementation[3]	Since Last AWMP[4]	5 Years in Future[5]	10 Years in Future[5]
10608.48.b (1)	Measure the volume of water delivered to customers with sufficient accuracy	Being Implemented	Substantial	Substantial	Substantial	
10608.48.b (2)	Adopt a pricing structure based at least in part on quantity delivered	Being Implemented	None	Substantial	Modest	Modest
10608.48.c (1)	Facilitate alternative land use for lands with exceptionally high water duties or whose irrigation contributes to significant problems, including drainage.	Not Technically Feasible	Not Applicable to BWGWD			
10608.48.c (2)	Facilitate use of available recycled water that otherwise would not be used beneficially, meets all health and safety criteria, and does not harm crops or soils.	Not Technically Feasible	Not Applicable to BWGWD			
10608.48.c (3)	Facilitate financing of capital improvements for on-farm irrigation systems	Being Implemented	Limited	Limited	Limited	
10608.48.c (4)	Implement an incentive pricing structure that promotes one or more of the following goals: (A) More efficient water use at farm level, (B) Conjunctive use of groundwater, (C) Appropriate increase of groundwater recharge, (D) Reduction in problem drainage, (E) Improved management of environmental resources, (F) Effective management of all water sources throughout the year by adjusting seasonal pricing structures based on current conditions.	Being Implemented	Substantial (Goals B, C & E)	Modest (Goals B, C & E)	Modest to Substantial (Goal A)	
10608.48.c (5)	Expand line or pipe distribution systems, and construct regulatory reservoirs to increase distribution system flexibility and capacity, decrease maintenance and reduce seepage	Being Implemented	Substantial	Substantial	Substantial	None to Modest, Depending on Funding and Opportunities
10608.48.c (6)	Increase flexibility in water ordering by, and delivery to, water customers within operational limits	Being Implemented	Substantial	Substantial	Substantial	None to Modest, Depending on Funding and Opportunities
10608.48.c (7)	Construct and operate supplier spill and tailwater recovery systems	Being Implemented	Substantial	Substantial	None to Substantial, Depending on Funding	
10608.48.c (8)	Increase planned conjunctive use of surface water and groundwater within the supplier service area	Being Implemented	Substantial	Substantial	Substantial	
10608.48.c (9)	Automate canal control structures	Being Implemented	None	Substantial	Substantial	None to Modest, Depending on Funding
10608.48.c (10)	Facilitate or promote customer pump testing and evaluation	Being Implemented	None	Modest	Limited	None
10608.48.c (11)	Designate a water conservation coordinator who will develop and implement the water management plan and prepare progress report.	Being Implemented	The activities of the Water Conservation Coordinator and other BWGWD staff to achieve WUE improvements through implementation of the EWMPs are described individually by EWMP.			
10608.48.c (12)	Provide for the availability of water management services to water users.	Being Implemented	Modest	Modest	None	None
10608.48.c (13)	Evaluate the policies of agencies that provide the supplier with water to identify the potential for institutional changes to allow more flexible water deliveries and storage.	Being Implemented	Modest	Modest	None to Substantial, Depending on Outcomes	
10608.48.c (14)	Evaluate and improve the efficiencies of the supplier's pumps.	Being Implemented	Substantial	Limited	Limited to Substantial, Depending on Technology and Funding	

1. As noted herein and throughout this analysis, reductions in losses that result in WUE improvements at the farm or district scale do not typically result in WUE improvements at regional scale, except in the case of evaporation reduction. All losses to seepage, spillage, tailwater, and deep percolation are recoverable within the BWGWD service area or by downgradient water users. Opportunities to achieve WUE through changes to the timing and amounts of water use may exist in some cases.

2. Quantitative estimates of improvements are not available. Rather, qualitative estimates are provided as follows, in increasing relative magnitude: None, Limited, Modest, and Substantial.

3. WUE Improvements occurring in recent years relative to if they were not being implemented.

4. WUE Improvements occurring in recent years relative to the level of implementation at time of last AWMP.

5. WUE Improvements expected in 2020 (five years in the future) and 2025 (ten years in the future), relative to level of implementation in recent years.

3.10 Attachments

This section includes the following attachments:

- 3.10.1 – Public Coordination and Adoption
- 3.10.2 – Rules and Regulations
- 3.10.3 – Agricultural Water Measurement Compliance Documentation
- 3.10.4 – Potential Projects to Enhance Water Management Capabilities
- 3.10.5 – Drought Management Plan

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3.10.1 Public Coordination and Adoption

Documentation of BWGWD's process for public review of this AWMP and adoption by its board of directors is provided on the following pages.

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PROOF OF PUBLICATION

No. BIGGS-WEST GRIDLEY WATER DIST.

In The Matter of

PUBLIC HEARING

(State of California)
(County of Butte) as
The undersigned resident of the County of Butte, State of California, says:

That I am, and at all time herein mentioned was a citizen of the United States and not a party to nor interested in the above entitled matter; that I am the principal clerk of the printer and publisher of:

The Gridley Herald

That said newspaper is one of general circulation as defined by Section 6000 Government Code of the State of California, Case No. 27,207 by the Superior Court of the State of California, in and for the County of Butte; that said newspaper at all times herein mentioned was printed and published twice a week (on Wednesdays and Fridays) in the City of Gridley and County of Butte; that the notice of which the annexed is a true printed copy, was published in said newspaper on the following days:

DECEMBER 2, 9, 2015

I certify (or declare), under penalty of perjury, that the foregoing is true and correct, at Gridley, California.

Dated **DECEMBER 9, 2015**
at Gridley, California

(Signature)

Notice of Public Hearing to Adopt Biggs-West Gridley Water District's 2015 Revised Agricultural Water Management Plan.

Notice is hereby given that on December 16, 2015 at 8 a.m., or as soon thereafter as the matter may be heard, the Biggs-West Gridley Water District (BWGWD) Board of Directors will hold a Public Hearing regarding the adoption of the 2015 Revision of the Feather River Regional Agricultural Water Management Plan (FRRAWMP) as BWGWD's Agricultural Water Management Plan (AWMP) which was prepared pursuant to California Water Code sections 10800 et seq. and Governor Brown's Executive Order B-29-15. An AWMP contains information regarding an agricultural water supplier's service area, information regarding the quantity and quality of its water resources, as well as the District's Drought Management Plan. BWGWD will receive comments regarding the FRRAWMP at the hearing, and then adopt the FRRAWMP as drafted or modified during or after the hearing. The BWGWD Board of Directors meeting to hear public comments regarding its AWMP, will take place at: 1713 W. Biggs Gridley Road, Gridley, CA 95948. Prior to the meeting, a copy of the proposed FRRAWMP will be available for public inspection at the same location. For more information, please call (530)846-3317.
Publish: December 2, 9, 2015 (The Gridley Herald)

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Biggs-West Gridley Water District

1713 WEST BIGGS GRIDLEY ROAD
GRIDLEY, CA 95948

PHONE: (530)846-3317
FAX: (530)846-5737

DIRECTORS
Gary N. Justeson, President
Tom Coleman, Vice President
Eric E. Waterbury, Sec./Treas.
Dominic B. Nevis
Michael W. Farr

Eugene Massa Jr., Gen. Manager

December 7, 2015

Paul Gosselin
Butte County Water Resource Conservation
308 Nelson Avenue
Oroville, CA 95965

RE: Notice of Intent to Prepare 2015 Agricultural Water Management Plan

Dear Mr. Gosselin:

Biggs-West Gridley Water District (BWGWD) is in the process of preparing a 2015 Agricultural Water Management Plan (AWMP) in accordance with Senate Bill x7-7 (SBx7-7), also known as the Water Conservation Act of 2009, which modifies Division 6 of California water Code, adding Part 2.55 (commencing with §10608) and replacing Part 2.8 (commencing with §10800).

The public review draft of the AWMP will be available for inspection from December 7 through December 15, 2015. Copies of the draft plan will be available at the BWGWD office located at 1713 W. Biggs Gridley Road, Gridley, CA 95948, as well as on the District's website: www.bwgwater.com.

The District will conduct a public hearing on the AWMP on December 16, 2015 at 8 a.m. at the District office, 1713 W. Biggs Gridley Road, Gridley, CA 95948, after which the District may adopt the plan. Public notices of the hearing will be advertised in the Gridley Herald prior to the hearing date.

For further information, please contact me at (530)846-3317, or emassa@bwgwater.com

Regards,

Eugene Massa, Jr.
District Manager

Biggs-West Gridley Water District

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Dominic B. Nevis
Michael W. Farr

Eugene Massa Jr., Gen. Manager

December 7, 2015

Vickie Newlin
Butte County Water and Resource Conservation
308 Nelson Avenue
Oroville, CA 95965

RE: Notice of Intent to Prepare 2015 Agricultural Water Management Plan

Dear Ms. Newlin:

Biggs-West Gridley Water District (BWGWD) is in the process of preparing a 2015 Agricultural Water Management Plan (AWMP) in accordance with Senate Bill x7-7 (SBx7-7), also known as the Water Conservation Act of 2009, which modifies Division 6 of California water Code, adding Part 2.55 (commencing with §10608) and replacing Part 2.8 (commencing with §10800).

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For further information, please contact me at (530)846-3317, or emassa@bwgwater.com

Regards,

Eugene Massa, Jr.
District Manager

Biggs-West Gridley Water District

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Tom Coleman, Vice President
Eric E. Waterbury, Sec./Treas.
Dominic B. Nevis
Michael W. Farr

Eugene Massa Jr., Gen. Manager

December 7, 2015

County of Sutter
Water and Resource Conservation
1130 Civic Center Blvd.
Yuba City, CA 95993

RE: Notice of Intent to Prepare 2015 Agricultural Water Management Plan

To Whom It May Concern:

Biggs-West Gridley Water District (BWGWD) is in the process of preparing a 2015 Agricultural Water Management Plan (AWMP) in accordance with Senate Bill x7-7 (SBx7-7), also known as the Water Conservation Act of 2009, which modifies Division 6 of California water Code, adding Part 2.55 (commencing with §10608) and replacing Part 2.8 (commencing with §10800).

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For further information, please contact me at (530)846-3317, or emassa@bwgwater.com

Regards,

Eugene Massa, Jr.
District Manager

Biggs-West Gridley Water District

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Gary N. Justeson, President
Tom Coleman, Vice President
Eric E. Waterbury, Sec./Treas.
Dominic B. Nevis
Michael W. Farr

Eugene Massa Jr., Gen. Manager

December 7, 2015

City of Gridley
685 Kentucky Street
Gridley, CA 95948

RE: Notice of Intent to Prepare 2015 Agricultural Water Management Plan

To Whom It May Concern:

Biggs-West Gridley Water District (BWGWD) is in the process of preparing a 2015 Agricultural Water Management Plan (AWMP) in accordance with Senate Bill x7-7 (SBx7-7), also known as the Water Conservation Act of 2009, which modifies Division 6 of California water Code, adding Part 2.55 (commencing with §10608) and replacing Part 2.8 (commencing with §10800).

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For further information, please contact me at (530)846-3317, or emassa@bwgwater.com

Regards,

Eugene Massa, Jr.
District Manager

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Tom Coleman, Vice President
Eric E. Waterbury, Sec./Treas.
Dominic B. Nevis
Michael W. Farr

Eugene Massa Jr., Gen. Manager

December 7, 2015

City of Biggs
PO Box 307
Biggs, CA 95917

RE: Notice of Intent to Prepare 2015 Agricultural Water Management Plan

To Whom It May Concern:

Biggs-West Gridley Water District (BWGWD) is in the process of preparing a 2015 Agricultural Water Management Plan (AWMP) in accordance with Senate Bill x7-7 (SBx7-7), also known as the Water Conservation Act of 2009, which modifies Division 6 of California water Code, adding Part 2.55 (commencing with §10608) and replacing Part 2.8 (commencing with §10800).

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For further information, please contact me at (530)846-3317, or emassa@bwgwater.com

Regards,

Eugene Massa, Jr.
District Manager

Biggs-West Gridley Water District

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Eric E. Waterbury, Sec./Treas.
Dominic B. Nevis
Michael W. Farr

Eugene Massa Jr., Gen. Manager

December 7, 2015

Barbara Vlamis
AquaAlliance
PO Box 4024
Chico, CA 95927

RE: Notice of Intent to Prepare 2015 Agricultural Water Management Plan

Dear Ms. Vlamis:

Biggs-West Gridley Water District (BWGWD) is in the process of preparing a 2015 Agricultural Water Management Plan (AWMP) in accordance with Senate Bill x7-7 (SBx7-7), also known as the Water Conservation Act of 2009, which modifies Division 6 of California water Code, adding Part 2.55 (commencing with §10608) and replacing Part 2.8 (commencing with §10800).

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The District will conduct a public hearing on the AWMP on December 16, 2015 at 8 a.m. at the District office, 1713 W. Biggs Gridley Road, Gridley, CA 95948, after which the District may adopt the plan. Public notices of the hearing will be advertised in the Gridley Herald prior to the hearing date.

For further information, please contact me at (530)846-3317, or emassa@bwgwater.com

Regards,

Eugene Massa, Jr.
District Manager

BIGGS-WEST GRIDLEY WATER DISTRICT

1713 WEST BIGGS GRIDLEY ROAD, GRIDLEY CA 95948
TELEPHONE: (530) 846 3317 FAX: (530) 846 5737
E-mail: emassa@bwgwater.com

BOARD OF DIRECTORS MEETING

DECEMBER 16, 2015- 8:00 a.m.

AGENDA

DRAFT

1) CALL TO ORDER – PRESIDENT, GARY JUSTESON

2) 2015 AGRICULTURAL WATER MANAGEMENT PLAN (Action Items)

A) PUBLIC HEARING –) Public Hearing on the Review and Approval of the 2015 Updated Feather River Agricultural Water Management Plan as BWGWD's 2015 Agricultural Water Management Plan, and Approve BWGWD Resolution 2015-11, Resolution to Adopt as Biggs-West Gridley Water District's 2015 Agricultural Water Management Plan and Drought Water Management Plan (*Action Item).*

3) PUBLIC PARTICIPATION – AGENDIZED AND NON AGENDIZED ITEMS

This item is on the agenda to provide the public time to address the Board on any topic that is not on the Agenda, or for topics that are on the agenda, but the individual cannot stay for this item to sequence. The Board may also hear any written correspondence addressed to the Board at this time. By filling out a card with the General Manager, citizens may make their interest in addressing the Board known. In order to not unduly delay the meeting, individuals requesting the opportunity to address the Board will keep their comments to a maximum of three minutes. The Board may undertake discussion only to provide clarification to the public or schedule a matter for a future meeting.

As a reminder, members of the audience may also submit a card to address the Board at any time prior to the Board's consideration of a specific item on the agenda. Said requests to address the Board on specific agenda items will be taken at the end of Board discussion for each agenda item. Speaker will be allowed a maximum of three minutes, and if said comment is redundant in nature, time period may be reduced at the discretion of the Chairman of the Board. Cards should be given directly to the General Manager during the meeting.

3) CLOSED SESSION:

A) CONFERENCE WITH LEGAL COUNSEL—ANTICIPATED LITIGATION
Significant exposure to litigation under paragraph (2) of subdivision (d) of Section 54956.9
(Number of potential cases:1) (*Possible Action Item).*

B) CONFERENCE WITH LEGAL COUNSEL – ANTICIPATED LITIGATION

Initiation of litigation pursuant to paragraph (4) of subdivision (d) of Section 54956.9 (Number of potential cases:1) (*Possible Action Item).*

4) SWRCB TEMPORARY URGENCY CHANGE ORDER DRAFT PROPOSAL

A) Discussion of SWRCB's Proposed Order denying in part and approving in part Petitions for Reconsideration of and addressing objections to the Executive Director's 2015 Temporary Urgency Change Orders (*Possible Action Item).*

5) ANNUAL MEETING – ORGANIZATION OF BOARD OFFICERS:

A) Nomination and Election of Board President (*Action Item) (Currently Justeson).*
B) Nomination and Election of Board Vice President (*Action Item) (Currently Coleman).*
C) Nomination and Election of Board Secretary/Treasurer *(Action Item) (Currently Waterbury)*
D) Dates and Times of Regular Board Meetings – Third Wednesday of the month at 8:00 a.m. *(Action Item).*
E) Committees: *(Action Item).*

1. Personnel Committee (*Action Item) (Currently Waterbury & Massa).*
2. Budget and Finance Committee (*Action Item) (Currently Waterbury & Coleman).*
3. Safety Committee (*Action Item) (Currently Bolley and Massa).*
4. Joint Board Representative *(Action Item) (Currently Nevis).*

6) MINUTES

A) Review and approval of the November 18, 2015, Regular Board Meeting minutes (*Action Item).*

7) FINANCIAL REPORT

A) Review and Receive 2014 Audit (*Action Item).*
B) Approval of December, 2015 payables (*Action Item).*
B) Review and Receive November, 2015 monthly financials *(Action Item).*
C) Hourly Employee Services Rendered Merit Pay - $500 (*Action Item).*
D) Cold Water Payment Authorization (*Action Item).*
i) None

8) SUMMER WATER (ALLOTTED) / FALL WATER (NON-ALLOTTED)

A) Non-Allotted / Fall Water Season
i) Status Update and When to Shut Off BWGWD's System (*Action Item).*

9) SGMA – SUSTAINABLE GROUNDWATER MANAGEMENT ACT

A) Groundwater Sustainability Agency Process Update *(Informational Only).*

10) GLWA CANAL PROJECT

A) Status Update *(Informational Only).*

11) MANAGEMENT AND BOARD REPORTS

A) Joint Board Report – Dominic Nevis

B) Other Manager's Reports *(Informational Only).*

C) Director's Reports *(Informational Only).*

12) PUBLIC RECORDS ACT REQUEST – FURTHER DEMAND

A) Request From Ryan Schohr for Water Data Reports on his Fields (*Action Item).*

13) DATE, TIME & LOCATION OF NEXT BOARD MEETING

Next scheduled Regular Board Meeting is January 20, 2016 at 8:00 a.m. (*Action Item).*

14) ADJOURN.

Note:

1) Any documents related to agenda items, other than closed session items, that are made available to the Board before the meeting will be available for review by the public at the Districts Office located at 1713 West Biggs Gridley Road, Gridley, California, during normal business hours.
2) In compliance with the Americans with Disabilities Act, if you need special assistance or accommodations to participate in this meeting, please contact Eugene Massa Jr. at the District's office at (530) 846-3317. Notification at least 48 hours prior to the meeting with enable the BWGWD to make reasonable arrangements to ensure accessibility to this meeting. This may include agendas in alternative formats. (28 CFR 35.101-35.164 ADA Title II.)

MEETING NOTIFICATION REQUESTS: If you would like to be notified of future Biggs West Gridley Water District meetings and events, please call Eugene Massa Jr. at (530) 846-3317 or email at emassa@bwgwater.com

Posted – Friday, December 11, 2015 - Eugene Massa Jr.

DRAFT

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BIGGS-WEST GRIDLEY WATER DISTRICT RESOLUTION NO. 2015-11

RESOLUTION TO ADOPT BIGGS-WEST GRIDLEY WATER DISTRICT'S AGRICULTURAL WATER MANAGEMENT PLAN AND DROUGHT MANAGEMENT PLAN

WHEREAS, the Legislature has adopted the Agricultural Water Management Planning Act (AWMPA), at Water Code sections 10800-10853, thereby requiring each agricultural water supplier, serving water to a minimum number of irrigated acres, to prepare and adopt an Agricultural Water Management Plan (AWMP) to achieve the conservation of water; and

WHEREAS, in 2014 the Biggs-West Gridley Water District (BWGWD), in compliance with the AWMPA did adopt the Feather River Agricultural Water Management Plan as BWGWD's AWMP; and

WHEREAS, at Water Code section 10820(a), requires agricultural water suppliers shall prepare and adopt an AWMP in the manner set forth on or before December 31, 2012, and shall update that plan on December 31, 2015, and on or before December 31 every five years thereafter; and

WHEREAS, on April 1, 2015 Governor Brown issued Executive Order B-29-15 mandating agricultural water supplies to include a detailed Drought Management Plan (DMP) describing actions and measures taken to manage water demand during droughts; and

WHEREAS, the Feather River Regional Agricultural Water Management Plan, as updated, does contain the requisite information for Biggs-West Gridley Water District's (BWGWD) required under California Water Code section 10608.48(d), Executive Order B-29-15, and the AWMPA.

NOW, THEREFORE, BE IT RESOLVED by this Board of Directors as follows:

1. The foregoing recitals and findings, and each of them, are true and correct.
2. That BWGWD does hereby adopt the 2015 Updated Feather River Regional Agricultural Water Management Plan, as updated and written, as its Agricultural Water Management Plan and Drought Management Plan.

I HEREBY CERTIFY that the forgoing is a true and correct copy of the resolution of the Board of Directors of BWGWD as duly passed and adopted by said Board on the 16th day of December, 2015.

Vote:

Coleman _AYE___; Farr _AYE__; Justeson _AYE__;

Nevis _AYE___; Waterbury _AYE___

President of the Board of Directors

By: _____
Gary Justeson

3.10.2 Rules and Regulations

BWGWD's rules and regulations are provided on the following pages.

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BIGGS WEST-GRIDLEY WATER DISTRICT

BYLAWS

AND

RULES AND REGULATIONS

1992

Bylaws of Biggs-West Gridley Water District

ARTICLE I

The Board of Directors shall meet in regular session on the second Thursday in each month, at the hour of 2:00 o'clock P.M., at the office of said District, provided, however, that the date and hour of holding such regular monthly meetings may be changed at any time by resolution of the Board of Directors entered on its minutes not less than thirty days prior to such change becoming effective. Every regular meeting and every special meeting may be adjourned from time to time and said adjourned meeting shall constitute a regular meeting or special meeting as the case may be.

Special meetings may be called, or held on consent of all Directors, as provided by the California Water District Act, and when so called or held, any business of the District may be transacted whether notice that said business was to be acted upon at said special meeting, was given or not.

ARTICLE II

The office of said District shall be at 1713 West Biggs-Gridley Road, Gridley, California 95948, but the location of said office may be changed by resolution entered on the minutes of the Board not less than thirty days before such change becomes effective.

ARTICLE III

The Directors shall choose from among its members, a president, who shall preside at all meetings of the Board and shall perform all other duties usually incumbent on such officer and all duties required of him by law or order of the Board of Directors. In his absence or inability to act his duties shall devolve upon a vice-president to be selected from their own number by the other Directors.

1

ARTICLE IV

The Board shall appoint a Secretary to hold office at the pleasure of the Board, who shall keep a full and correct record of the proceedings of the Board of Directors, and shall have charge of all books, maps, and papers of the District, except those required by the Assessor-Tax Collector, Treasurer or Manager. He shall perform all duties usually appertaining to such office, and those required by law or the order of the Board. The Secretary need not be a resident or holder of title to land in the District and his salary shall be fixed by resolution of the Board. He shall carry an official bond in not less than the sum of $50,000.00.

ARTICLE V

The offices of Assessor and Tax Collector of the District may be consolidated into one office and the Treasurer appointed by the Board to serve at its pleasure.

The person holding such office of Treasurer shall keep a full and correct record of the finances of the District. He shall keep, in a separate book for that purpose, a record of each warrant drawn by him, on order of the Directors, showing the date, number, the name of the person to whom and for what services the same was issued. He shall also perform all duties usually incumbent on such office and all duties required by him by law, and all duties required of him by the terms of the bonds issued by this District. He shall draw no warrants unless ordered by the Directors, except for salaries which have been fixed by the Board. He may, with approval of the Board, appoint a deputy whose salary and bond, if any, shall be fixed by the Board.

The person holding such consolidated office shall as Assessor keep a full and correct record of all work done by him and shall do all things required by him to be done as provided by law.

The person holding such consolidated office shall as Tax Collector collect all taxes or assessments due the District and shall keep an accurate record thereof showing

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the amounts collected, on what parcels and from whom collected. He may, with the approval of the Board, appoint a deputy whose salary, and bond, if any, shall be fixed by the Board.

The salary for the consolidated office of Assessor and Tax Collector and the office of Treasurer shall be fixed by Resolution of the Board, and said officers shall be required to carry an official bond in not less than the sum of $1,000.00.

ARTICLE VI

The Board shall also employ a manager of the District who shall attend to the maintenance and operation of the works of the District, and the distribution of water and such other duties as may be delegated to him by the Board. The salary of the manager shall be fixed by resolution of the Board.

ARTICLE VII

The Directors, in addition to the powers conferred by law, shall have full power and authority to do any and all things necessary to effect the work of irrigation of lands of the District, and for the management and control of the same and of the affairs of the District.

The Directors shall have such powers as are now or may be hereafter conferred on them by law. Each Director shall receive compensation in an amount not to exceed fifty dollars ($50) per day for each day's attendance at meetings of the Board for each day's service rendered as a Director by request of the Board, not exceeding a total of six days in any calendar month, together with any expenses incurred in the performance of his duties required or authorized by the Board.

Prior to April 1st of each year, the Board shall by resolution adopt rules and regulations, not inconsistent herewith, for the operation of the District and sale and distribution of water, and fix the rates to be charged for water for that year.

3

ARTICLE VIII

All claims against the District shall be presented in writing, and filed with the Secretary.

ARTICLE IX

These Bylaws may be amended by a four-fifths vote of the Directors, provided that before the amendments take effect, the Board of Supervisors of Butte County, State of California, shall approve the amendments in writing.

ARTICLE IX

Should a vacancy exist in any of the offices of the District, it may be filled by appointment by a majority of the Board of Directors.

ARTICLE XI

All elected officers of the District shall hold office respectively for four (4) years next succeeding their election and until their successors are elected and qualified. Election of officers shall be held and conducted pursuant to and in accordance with the Uniform District Election Law and Division 13 (California Water Districts) of the Water Code of the State of California.

For the purposes of said elections, there shall be but one election precinct, the boundaries of which shall be coterminous with the boundaries of the District. Each holder of title or evidence of title shall have the right to vote at any and all elections held in the District either in person, or by written proxy.

The foregoing Bylaws of Biggs-West Gridley Water District having been read and considered by the Board of Supervisors of Butte County, State of California, pursuant to resolution of said Board of Supervisors, duly made, seconded and carried, said Bylaws are hereby approved in writing by said Board of Supervisors.

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RULES AND REGULATIONS
Governing the Use and Distribution of Water
in the Biggs-West Gridley Water District
and
Rates of Tolls and Charges for the Use Thereof

RULE 1. CONTROL OF SYSTEM

The maintenance and operation of the canals, drains, and works of the District shall be under exclusive management and control of the Manager, appointed by the Board of Directors, and no other persons, except his employees and assistants, shall have any right to interfere with said canals, drains and works in any manner, except in case of an order from the Board of Directors.

RULE 2. INSTALLATION OF GATES

No gate, takeout, siphon or other structure or device shall be installed or placed in any canal, ditch or conduit belonging to the District except in pursuance of plans adopted or orders made by the Board of Directors, nor shall any person divert or take water from any canal, ditch or conduit belonging to the District or under its control, or make any opening therein, or change, molest, disturb or interfere with any gate, takeout or other structure or device in any such canal, ditch or conduit without permission of the ditchtender in charge thereof or the Manager.

RULE 3. PRIVATE DITCHES

All private ditches shall be maintained and kept clean by the users thereof at no cost to the District and shall be of sufficient size to carry the irrigation head ordered. The Manager shall examine all private ditches before water is turned in and shall certify on the application for water whether the ditch leading to each applicant's land is in proper condition to carry water. In case any ditch is found not to be in accordance with this rule, the water shall not be turned into it until this rule is complied with provided that where private ditches of less capacity than herein required were constructed prior to the year 1943 the owners shall be

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allowed a reasonable time to enlarge them if the Manager shall find that such enlargement is necessary.

Where ditches must be constructed or enlarged to carry water from existing District laterals to land to be served, the land owner or user requesting water must provide the right of way and construct or enlarge at no cost to the District a service ditch from said land to a District lateral designated by the Manager.

The District shall have control of all diverting gates and weirs in private ditches to such an extent as may be necessary to enforce the delivery of water in accordance with these Rules and Regulations, but the District shall not thereby assume or incur any liability for the maintenance or repair of such gates and weirs. Only District employees or persons delegated by them shall have authority to open such diverting gates and they shall have full authority to close such gates as soon as the proper amount of water for each irrigation has been discharged. Such gates may be equipped with locks, and the keys thereof shall be under the control of the Manager.

RULE 4. DISTRIBUTION OF WATER

Except as otherwise herein provided, all waters shall be apportioned ratably to the lands of the District, upon such landowners making proper application therefor under these Rules and Regulations and making payment of the tolls and charges fixed by the Board. Upon failure of any landowner to make application for water or pay tolls and charges, the water belonging to such landowner may be allotted by the District to other landowners offering to make the required payments therefor.

RULE 5. APPLICATIONS FOR WATER

Before April 1st of each year, unless it falls on a weekend, then the following Monday, each landowner or user desiring water shall file with the secretary a statement and application for water on a form provided by the District, setting forth the crops and acreage of each crop he is intending to irrigate and which statement and application

shall further contain the name of the owner, name of tenant, or tenants, acreage and location of acreage for which water is desired, and such other matters as the Board of Directors may deem necessary, which application shall grant a right to the District to control all ditches and laterals, and to install, maintain, control and regulate all meters, measuring devices, delivery gates or other structures in any ditch, canal or lateral necessary for the distribution, measurement and control of water. Provided, however, such control and right to maintain and regulate shall not impose a duty to do so, or liability for damages resulting from the use of such ditches, laterals, meters, measuring devices, delivery gates or other structures, or otherwise arising. Such time within which applications for water must be made may be extended or changed by resolution and order of the Board of Directors.

The application for water shall provide, among other conditions, that:

Application hereby agrees and stipulates that if applicant or any of its tenants or agents shall pump any water from the underground strata's underlying the land upon which the subject water is to be utilized and if any of such underground water pumped and utilized upon the properties of applicant shall migrate or travel from the boundaries of the properties of applicant that such water shall become the sole and exclusive property of District and District may utilize such water without charge for the purpose of sale or provision to other lands lying within the same groundwater basin as applicant's lands. District does not by the terms of this Agreement accept any liability for damages or injuries arising from the escape or migration of groundwaters made subject to this Agreement from time to time and landowner shall be solely responsible that the quantities of water or manner of migration are reasonable and do not damage others.

RULE 6. DELIVERY OF WATER

Notice must be given for all request of water service at least forty-eight hours before the water is needed. Effort will be made to make delivery in less than two days,

and where possible, delivery will be made within twenty-four hours.

All shut-off orders must be sent to the District office or given to the ditchtender no later than two o'clock P.M., on the day before such shut-off is desired. When service is desired for shorter periods than one day, the shut-off order must accompany the request for service.

Water must be used continuously by the water user throughout the period of delivery, both day and night.

RULE 7. MEASUREMENTS AND MEASURING DEVICES

The District shall be entitled to place meters, or other measuring devices, turnouts, gates, or other structures in the ditches, canals and laterals as it may consider necessary or proper. Cost of measuring devices and gates shall be paid for by landowner with the labor for installation being provided by District.

RULE 8. TIME OF FIXING RATES OF TOLLS AND CHARGES

The rates of tolls and charges for the use of water shall be fixed and determined annually by the Board of Directors between the first day of January and the fifteenth day of April of each year.

RULE 9. PAYMENT OF CHARGES FOR WATER

(a) The established rates of tolls and charges for water used in the irrigation of crops are payable as follows: *fifty percent shall be paid before water is applied to lands, with the remaining fifty percent and balance of said water charge payable on or before July 1st.* Payment of the balance of water charge shall become delinquent thirty days after due date, and shall be subject to an interest charge of one and one-half percent per month.

(b) Accepting Security in Lieu of Cash. The Board of Directors may in its discretion, in lieu of payment of tolls and charges in cash, accept security for such payment, payable from crops to be grown or such other and /or

additional security as may be acceptable to said Board of Directors. All costs in connection with such security are to be paid by the landowners or water user.

(c) Penalty on Water Charges. All tolls and charges not paid when due shall be charged in addition thereto penalty at the rate of one and one-half percent (1½%) per month or eighteen percent (18%) per annum.

(d) Shutting Off Water. If water charges are not paid when due, the Board may in its discretion shut off the service of water until the charges are paid. This includes the right to shut off water regardless of the type of crop being irrigated or the use to which the water is being put and regardless of whether the user thereof is a landowner, tenant or other user.

In the event any water charges are unpaid at the end of an irrigation season on any particular land, the District, through its Board, may in its discretion refuse to serve water to that land in the following or subsequent seasons, until all such unpaid water charges are paid in full. This shall include the right to refuse service of water although the user of the water for which charges remain unpaid was not the owner of the land, and although the ownership of the land may have changed since the water, for which the charges remain unpaid, was used.

In the event service of water is shut off as herein before provided for, neither the Board, the District, or its officers, agents or employees, shall be liable for any damage which may occur as a result thereof.

RULE 10. ACREAGE SURVEYS

If the District finds it necessary to survey land for the purpose of determining the acreage planted and for which water was delivered, it will include all and is within the exterior boundaries of the planted area on which water has been allowed to stand.

RULE 11. USE OF WATER FROM DRAINS AND WATER COURSES

The District may charge any user or land owner

pumping or diverting in the District water from drains or natural water courses and using such water upon lands within the District the regular rates and charges herein established.

RULE 12. WASTE OF WATER

Any consumer wasting water on roads or vacant land, or land previously irrigated either willfully, carelessly, or on account of defective ditches, or who shall flood certain portions of land to an unreasonable depth, or use an unreasonable amount of water in order to properly irrigate other portions, or whose land has been improperly checked for the economical use of water, may be refused the use of water until such conditions are remedied.

The District and its Board of Directors reserve the right to refuse delivery of water to any lands when it appears to the satisfaction of the Board of Directors that its proposed use, or method of use, will require such extensive quantities of water, as will constitute waste.

RULE 13. SHORTAGE OF WATER

When, through lack of water, lack of ditch capacity, or for any other reason, it is not possible to deliver throughout the District or any portion thereof, the full supply of water required by the water users, such supply as can be delivered will be equitably prorated until such time as delivery of a full supply can be given.

In the discretion of the Board, in periods of water shortage, prior right to water may be given those users whose applications were received before April 1st of that year, over those whose applications were received subsequent to that date.

RULE 14. COMPLAINTS

All complaints as to service, lack of water, or other unsatisfactory conditions, should be made immediately, in writing, addressed to the Manager of the District at the District office.

RULE 15. ACCESS TO LAND AND DITCHES

The authorized ditchtenders and other agents of the District shall have free access at all times to all lands irrigated from the canal system and to all canals, laterals and ditches, for the purpose of inspection, examination, measurements, surveys, or other necessary purposes of the District, with the right of installation, maintenance, control and regulation of all meters or other measuring devices, gates, turnouts, or other structures necessary or proper for the measurement and distribution of water.

Said District assumes no liability for damages to persons or property occasioned through defective ditches, laterals, meters or measuring devices.

RULE 16.ENFORCEMENT OF RULES

Refusal to comply with these requirements or any transgression of any of the foregoing Rules or Regulations or any interference with the proper discharge of the duties of any person employed by the District shall be considered sufficient cause for shutting off the water, and water will not again be furnished until in the opinion of the Board of Directors full compliance has been made with all requirements herein set forth.

RULE 17. NON-LIABILITY OF DISTRICT

The District will not be liable for any damage of any kind or nature resulting directly or indirectly from any private ditch or the water flowing therein or by reason of lack of capacity therein, or for negligent, wasteful or other use of handling of water by the users thereof, and its responsibility shall absolutely cease when the water leaves the canal of the District; nor will the District be liable for shortage of water, either temporary or permanent, or for failure to deliver such water; nor will the District be responsible for the temperature or quality of the water.

RULE 18. DAMAGE TO CANAL OR BANKS

Where a farmer or livestock man finds it necessary to run livestock in fields through which any ditches or

laterals of the District run either by easement or right of way, the farmer or livestock owner will be responsible to the District for damages to canals or banks caused by such livestock. He must either repair the damage himself to District Manager's satisfaction or pay the District's cost for making the repairs.

RULE 19. WHEELING IN DISTRICT FACILITIES

Anyone using the District ditches to wheel or transfer non-District water must first request authorization to utilize the District facility and then they will be charged the same rate per acre feet that RD 833 charges the District for wheeling privileges.

Revised March 1, 1993.

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3.10.3 Agricultural Water Measurement Compliance Documentation

Introduction

Pursuant to the Water Conservation Act of 2009, California Water Code (CWC) §10608.48(b) requires that on or before July 31, 2012 agricultural water suppliers shall measure the volume of water delivered to customers with sufficient accuracy to:

- Adopt a pricing structure for water customers based at least in part on quantity delivered
- Submit an annual report to the Department of Water Resources that summarizes aggregated farm-gate water delivery data on a monthly or bi-monthly basis

Under the authority provided for in CWC §10608.48(b), the California Department of Water Resources adopted the regulations summarized below pertaining to Agricultural Water Measurement, which became effective on July 11, 2012. Those regulations are contained in the California Code of Regulations Title 23 Division 2 Chapter 5.1 Article 2 Section 597 (CCR 23 §597 or Regulation) and apply unconditionally to agricultural suppliers serving more than 25,000 acres and to suppliers serving between 10,000 acres and 25,000 acres if funding is provided. The permanent regulation was approved by the Office of Administrative Law on July 11, 2012.

The Regulation requires measurement at individual customer delivery points or, provided specific conditions exist, at points serving multiple customers.

Biggs–West Gridley Water District (BWGWD) provides agricultural water delivery to customers whose aggregate acreage exceeds 25,000 acres and is therefore subject to the Regulation.

Compliance Requirements

<u>Measurement Accuracy</u>

According to CCR 23 §597, specific accuracy thresholds apply to different measurement devices. Existing measurement devices shall be certified to be accurate to within ±12 percent by volume and new or replacement measurement devices shall be certified to be accurate to within:

- ±5 percent by volume in the laboratory if using a laboratory certification; or
- ±10 percent by volume in the field if using a non-laboratory certification

In order to comply with CCR 23 §597, BWGWD is implementing improvements identified in its evaluation of customer delivery measurement options (ECDMO), prepared during 2012 and described below. Specifically, a new, acoustic Doppler velocimeter device called the RemoteTracker will be used to measure deliveries to customers. The RemoteTracker satisfies the requirement to be accurate within ±5 percent by volume based on a laboratory certification within the ECDMO, which is attached for reference.

Accuracy Certification

The RemoteTracker system is certified to be accurate to within ±5 percent by volume as described in the attached ECDMO.

BWGWD Compliance Actions

During the 2012 irrigation season, Davids Engineering (DE) prepared an ECDMO for BWGWD that consisted of the following three tasks:

1. Perform an inventory of BWGWD farm-gate deliveries, including establishing GPS coordinates and critical physical characteristics such as pipe size, gate type, and available head,
2. Evaluate three potential measurement options for compliance with accuracy standards specified in CCR 23 §597, including estimated capital costs, and
3. Conduct pilot testing of the RemoteTracker measurement system, including developing and testing measurement data collection protocols and customer billing processes.

For Task 2, three alternative measurement approaches were evaluated:

1. Maximum Use of Existing Devices
2. RemoteTracker System
3. Propeller Meters

The ECDMO report includes a certification that the volumetric accuracy of the RemoteTracker system meets the accuracy standards of CCR 23 §597 and a corrective action plan for the district to implement to meet those standards.

At a regularly scheduled meeting on January 16, 2013, the BWGWD Board of Directors considered the ECDMO report and the customer delivery measurement options presented therein. By unanimous vote, the board accepted the report and adopted the RemoteTracker System as the district's preferred approach to implement a compliant customer delivery measurement program. In addition to being compliant with the measurement accuracy standards specified in CCR 23 §597 the program is capable of supporting implementation of a water rate structure based in part on the volume of water delivered.

Due to the capital improvement cost of implementing the customer delivery measurement program being relatively large in comparison to the district's revenue and operating budgets, the board also unanimously agreed that the program will be implemented as discretionary revenue above operating and maintenance funds become available.

As of December 2015, the District has made the following improvements/changes to its infrastructure and data management and accounting capabilities to implement the RemoteTracker system and adopt a rate structure based in part on the volume of water delivered:

1. Procured RemoteTracker equipment required for each operator for district-wide

implementation of the RemoteTracker System,

2. Developed volumetric delivery accounting and reporting system with billing capabilities,
3. Adopted a pricing structure based in part on the volume of water delivered,
4. Installed approximately 100 weir boxes at gravity turnouts to allow for RemoteTracker system measurement at additional turnouts, and
5. Planned installation of an additional 150 to 200 weir boxes at turnouts to allow for RemoteTracker system measurement prior to the 2016 irrigation season.

BWGWD will continue to implement the customer delivery program as funds become available. BWGWD's ECDMO is provided on the following pages.

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Biggs-West Gridley Water District

Evaluation of Customer Delivery Measurement Options

Butte County, California

Prepared by

DAVIDS ENGINEERING, INC

December 2012

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Abbreviations

ADV	Acoustic Doppler Velocimeter
AF	acre-feet
BWGWD	Biggs-West Gridley Water District
CCR	California Code of Regulations
CDMP	Customer Delivery Measurement Plan
cfs	cubic feet per second
DWR	California Department of Water Resources
ft	feet/foot
ft/s	feet per second
gpm	gallons per minute
RID	Richvale Irrigation District
SNR	Signal-to-Noise Ratio
WCD	Wireless Computing Device
WIS	Water Information System
WMM	U.S. Bureau of Reclamation Water Measurement Manual
WSE	Water Surface Elevation
WWAN	Wireless Wide Area Network
WWVS	Wireless Water Velocity Sensor

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ES-1.0 Executive Summary

ES-1.1 Introduction

Biggs-West Gridley Water District (District or BWGWD) is located in the Sacramento Valley in southern Butte County, Northern California. The District operates and maintains a canal and lateral distribution system that supplies water to roughly 32,000 acres. The primary crop grown within the District is rice. BWGWD's service area also includes portions of the Gray Lodge Wildlife Management Area. The District holds pre-1914 water rights to Feather River water in conjunction with three other districts that make up the Joint Water Districts Board (Richvale Irrigation District, Butte Water District and Sutter Extension Water District).

Due to the unique characteristics and measurement challenges associated with rice water delivery, farm turnout measurement has evolved differently in BWGWD (and in most other rice-dominated water suppliers) as compared to some other suppliers in California. Historically, the District's canal system has been operated based on the management of canal water levels (or pools). With canal water levels held at targeted elevations, certain field-specific gate settings will deliver the necessary rice flood up and maintenance flows. The field-specific gate settings have been determined from years of experience and have been calibrated to deliver sufficient water without causing excessive tailwater. Operating in this manner, appropriate amounts of water are delivered to rice fields without the need to measure delivery rates or volumes. In summary, the operation consists of setting and adjusting turnout gate opening as needed to maintain desired field conditions and adjusting water deliveries into canals as needed to maintain targeted water levels. Flow adjustments are made based on approximations and rules of thumb, and there has been no need to measure water precisely to achieve "good" water management, provided that field tailwater and canal spills are held within reasonable limits.

Senate Bill X7-7 (the "Water Conservation Act") was enacted in November 2009, requiring all water suppliers to increase water use efficiency. Agricultural water suppliers, such as BWGWD, are mandated to prepare and adopt agricultural management plans by December 31, 2012, and update those plans by December 31, 2015, and every 5 years thereafter. The Water Conservation Act included Water Code section 10608.48(i)(1) directing the California Department of Water Resources to adopt regulations providing for a range of options that agricultural water suppliers may use to implement volumetric measurement of farm-gate water deliveries. The resulting regulation, California Code of Regulations Title 23 Division 2 Chapter 5.1 Article 2 Section 597 et seq. (CCR 23 §597), mandates that, on or before July 31, 2012, agricultural water suppliers subject to the law shall measure the volume of water delivered to customers with sufficient accuracy to:

- Enable reporting of aggregated farm-gate delivery data to the State and
- Adopt a pricing structure based at least in part on the quantity of water delivered.

CCR 23 §597 requires that existing farm turnouts like those in the District have a measurement accuracy of ±12 percent by volume, meaning that the measured volume of water delivered at each farm-gate (i.e.

turnout) must be no greater than 12 percent more, or 12 percent less, than the actual volume delivered. Additionally, any new or replacement measurement devices installed must be accurate to within:

- ±5 percent by volume in the laboratory if using a laboratory certification;
- ±10 percent by volume in the field if using a non-laboratory certification

The regulation mandates that an accuracy certification be performed by either: (1) field testing of a random and statistically representative sample of existing farm turnouts, (2) field inspections and analysis of every existing farm turnout, with the testing or inspections documented by a registered engineer, or (3) a laboratory certification.

The purpose of this document is to summarize the activities and analysis performed by Davids Engineering during 2012 in support of the District's evaluation of options for customer delivery measurement that are mandated by CCR 23 §597. The evaluation of options was comprised of the following three tasks:

1. Preparing an inventory of BWGWD delivery gates, including establishing GPS coordinates and critical physical characteristics, including turnout pipe size, gate type and available head.

2. Pilot testing of RemoteTracker operation, and developing and testing measurement data collection and customer billing processes during the 2012 irrigation season.

3. Evaluating alternative measurement devices and compliance approaches, including estimated capital costs.

This report documents the work completed according to the three tasks described above. The report is organized into the following five sections:

- **1.0 Introduction** - Provides information about BWGWD, its existing measurement practices, CCR 23 §597 and the purpose of this report
- **2.0 Farm Turnout Inventory** - Summarizes the findings of the farm turnout inventory
- **3.0 Alternative Measurement Devices** - Presents overviews of four measurement devices, including their respective abilities to meet the accuracy mandates of CCR 23 §597
- **4.0 Alternative Measurement Approaches –** Describes three measurement approaches for District-wide measurement based on the four measurement devices described in Section 3.0
- **5.0 Cost Estimates** - Provides reconnaissance-level capital cost estimates for the three measurement approaches developed in Section 4.0
- **6.0 Corrective Action Plan** - Presents basic overview of BWGWD's selection of a preferred measurement approach

ES-1.2 Farm Turnout Inventory

An inventory was performed during the 2012 irrigation season to identify all existing farm turnouts in the District and to characterize each farm turnout with respect to factors related to application of the four possible measurement devices evaluated.

Figure ES-1 provides a summary of the farm turnout inventory. A total of 359 farm turnouts were identified during the inventory. Of the total of 359 farm turnouts, 329 are served by supply canals and 30 are served by drainage channels (drains). Of the 329 farm turnouts served by supply canals, 321 turnouts operate by gravity and 8 are pumped. All 30 farm turnouts served by drains are pumped. Of the 321 gravity farm turnouts served by supply canals, 279 are controlled by orifice gates (gates) and 42 are controlled by other means (e.g. alfalfa valves, weir structures, or other). Just 29 of the 279 gate-controlled gravity farm turnouts have weir boxes. None of the 42 turnouts from supply canals controlled by other means have weir boxes.

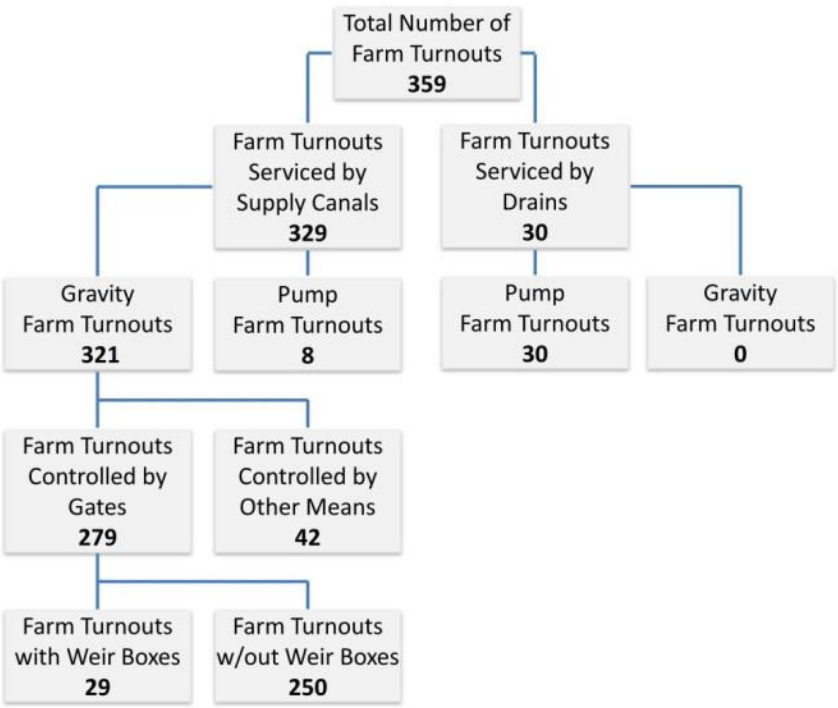

Figure ES-1. Farm Turnout Inventory Summary

ES-1.3 Alternative Measurement Devices

Four measurement devices were evaluated for potential application to achieve compliance with the CCR 23 §597 accuracy mandates. Although presently not used for measurement (see Section 1.2), the existing farm turnout gates could be used for measurement based on the submerged orifice principle. Alternatively, the weir boxes that have been installed at 29 turnout pipe outlets could be used for measurement based on the weir principle. These two existing devices are described further in Sections

3.1 and 3.2. In addition to the existing orifice gates and weir boxes, two new measurement devices were considered for compliance with CCR 23 §597, including the RemoteTracker system and propeller meters. These devices are discussed in Sections 3.3 and 3.4.

ES-1.3.1 Gates

Discharge through a submerged orifice gate can be computed with the Bernoulli equation. Data from previous investigations (Davids Engineering 2012) indicates that orifice gates can measure within the CCR 23 §597 accuracy mandate for existing measurement devices (±12 percent) provided that:

- Gate-specific variable coefficients based on multiple measurements at each gate are developed and
- Sufficient headloss occurs through the orifice gate to facilitate differential head measurements with low relative uncertainty (i.e. gates not operating near fully open position leading to minimal headloss through the gate and high relative uncertainties in water level measurements)

Hydraulic analysis of a 24 inch orifice gate indicates that, if a 12 cubic foot per second (cfs) flood flow is desired, a minimum of 0.5 feet of head is required. Based on this criterion, and the survey information discussed in Section 2.6, 172 of the 321 gravity farm turnouts (54 percent) have enough head to measure with an orifice gate.

ES-1.3.2 Weirs

Weirs installed in boxes placed at the turnout pipe outlets operate as standard suppressed rectangular weirs because the weir crest occupies the full box width (i.e., there is no flow contraction). Data from previous field investigations (Davids Engineering 2012) indicates that weirs can measure within the CCR 23 §597 accuracy mandate for existing measurement devices (±12 percent) provided that:

- Sufficient head (drop) is available between the canal water level and field water level
- Leakage through weir boards is stopped (or accounted for)

Hydraulic analysis of a four foot wide weir box indicates that, if a 12 cubic foot per second (cfs) flood flow is desired, a minimum of 1.5 feet of head is required. Based on this criterion, and the survey information discussed in Section 2.6, 123 of the 321 gravity farm turnouts (38 percent) have enough head to measure with a weir.

ES-1.3.3 RemoteTracker System

The RemoteTracker is an integrated turnout flow measurement, data management and volumetric accounting system developed by H2oTech specifically for agricultural water suppliers. The RemoteTracker system is comprised of (1) a wireless water velocity sensor, (2) a ruggedized tablet PC carried in the operator's vehicle and (3) a database residing on a file server connected to the tablet PC

via a cellular internet connection. The RemoteTracker system is compliant with the volumetric accuracy mandates of CCR 23 §597. See Appendix A for a laboratory based volumetric accuracy certification of the RemoteTracker system. The RemoteTracker system can provide accurate flow data over all farm turnout head ranges.

ES-1.3.4 Propeller Meters

Using propellers meters for farm turnout measurement involves permanently installing a propeller meter device at each farm turnout. Propeller meters have a propeller that is placed in the outfall of the farm turnout pipe. Laboratory certifications of flow measurement accuracy are available for most commercially available propeller meters. Since propeller meters are permanently installed devices, volumetric accuracy is the same as flow rate accuracy. Therefore, propeller meters are compliant with the volumetric accuracy mandates of CCR 23 §597. Propeller meters can provide accurate flow data over all farm turnout head ranges.

ES-1.4 Alternative Measurement Approaches

To facilitate the development of measurement approaches, all farm turnouts within the District were classified into one of four farm turnout categories:

1. Low Head Gravity (i.e. head less than 0.5 feet),
2. Medium Head Gravity (i.e. head between 0.5 and 1.5 feet),
3. High Head Gravity (i.e. head greater than 1.5 feet) and
4. Pump (i.e. water supplied to fields via pumps).

Table ES-1 presents a summary of three measurement approaches considered to be potentially viable for the District to comply with CCR 23 §597. Table 5 indicates the number of turnouts falling in each category and, for each approach, the measurement device that would be used for each category. The three approaches are discussed in greater detail in Sections 4.1 through 4.3. None of the measurement devices discussed in Section 3 can be utilized to measure pump deliveries. Therefore, all three approaches include the use of totalizing flow meters at the 38 pump deliveries within the District.

Table ES-2 summarizes the different levels of turnout improvement needed for each of the farm turnout categories, and the number of turnouts in each improvement level. All measurement approaches require gravity farm turnouts to have an orifice gate and a weir box. All pump farm turnouts require a totalizing flow meter. The classifications have been developed to be mutually exclusive so that each farm turnout only corresponds with one improvement classification within the table, which facilitates the ability to sum the number of farm turnouts in each row to develop the total number or farm turnouts in each farm turnout category. The Gray Lodge project will be replacing or retrofitting a number of gravity farm turnouts in each classification; therefore, a 'Gray Lodge' classification is necessary to avoid double counting.

Table ES-1. Measurement Approach Summary

Farm Turnout Category	Count of Farm Turnout Categories	Measurement Devices		
		Approach 1 - Maximum Use of Existing Devices	Approach 2 - RemoteTracker System	Approach 3 - Propeller Metering Program
Low Head Gravity (H < 0.5 feet)	**26**	Propeller Meters	RemoteTracker System	Propeller Meters
Medium Head Gravity (0.5' < H < 1.5')	**172**	Orifice Gates		
High Head Gravity (H > 1.5'	**123**	Weir Boxes		
Pump	**38**	Totalizing Flow Meters	Totalizing Flow Meters	Totalizing Flow Meters

Table ES-2. Farm Turnout Improvement Classification Count Summary

Farm Turnout Category	Farm Turnout Improvement Classification Counts						Sum
	Requires Orifice Gate and Weir Box	Requires Orifice Gate Only	Requires Weir Box Only	Requires No Improvements	Improvements by Gray Lodge Project	Requires Totalizing Flow Meter	
Low Head Gravity (H < 0.5 feet)	10	0	11	4	1	n/a	26
Medium Head Gravity (0.5' < H < 1.5')	22	0	95	12	43	n/a	172
High Head Gravity (H > 1.5'	7	0	60	5	51	n/a	123
Pump	n/a	n/a	n/a	0	0	38	38
Totals	39	0	166	21	95	38	**359**

ES-1.4.1 Approach 1 - Maximum Use of Existing Devices

Approach 1 is based on maximizing the use of existing measurement devices; however, neither of the two existing measurement devices (i.e. orifice gates and weir boxes) alone unconditionally meets the volumetric accuracy mandates of CCR 23 §597 across all gravity farm turnouts. Therefore, to achieve maximum use of existing devices, a hybrid approach involving multiple measurement devices is

necessary. Approach 1 utilizes weir boxes for high head gravity farm turnouts and orifice gates for medium head gravity farm turnouts. Propeller meters, a new device, would be used for low head gravity farm turnouts because neither gates nor weirs work under low head conditions. Measurement of the 38 pump deliveries in the District requires the installation of totalizing flow meters.

ES-1.4.2 Approach 2 - RemoteTracker System

Approach 2 involves the use of the RemoteTracker system at all gravity farm turnout categories (i.e. high head, medium head and low head gravity farm turnouts). Measurement of the 38 pump deliveries in the District requires the installation of totalizing flow meters.

ES-1.4.3 Approach 3 - Propeller Metering Program

Approach 3 involves the use of propeller meters at all gravity farm turnout categories (i.e. high head, medium head and low head gravity farm turnouts). Measurement of the 38 pump deliveries in the District requires the installation of totalizing flow meters.

ES-1.5 Reconnaissance-Level Cost Estimates

BWGWD, along with other agricultural and urban water suppliers, filed a Test Claim with the Commission on State Mandates alleging that the Water Conservation Act constitutes a reimbursable state mandate. That Test Claim is pending before the Commission and it is anticipated that a hearing will be held in September, 2013, and a decision will be made shortly thereafter. BWGWD, along with other agricultural water suppliers, are in the process of filing a supplemental Test Claim challenging CCR 23 § 597. If the Test Claims are successful, BWGWD will be entitled to reimbursement of all direct and indirect costs of compliance with the Water Conservation Act and 23 CCR § 597, including initial and annualized capital and maintenance and operation costs of farm-gate measurement devices.

Table ES-3 provides reconnaissance-level (1) initial capital, (2) annualized capital and (3) annual maintenance cost estimates for full scale implementation of the three measurement approaches discussed in Section 4. Each approach lists two possible scenarios regarding the farm turnouts within the Gray Lodge project. The left column reflects the annualized capital and maintenance cost under the conditions that certain improvement requirements for farm turnouts within the Gray Lodge project will be covered by an entity other than the District. The right column reflects the annualized capital and maintenance cost for all improvements including the farm turnouts within the Gray Lodge project. The annualized maintenance cost, which is unchanging in either scenario, will be the sole responsibility of the District. The last row provides the annualized capital and maintenance cost estimates. Differences among the three approaches with respect to operation costs (primarily labor and transportation) are not considered significant; therefore they are not included. A five percent interest rate was used for all calculations.

Table ES-3. Reconnaissance-Level Capital Cost Estimates for Three Measurement Approaches

Cost Category	Measurement Program Cost Estimate					
	Approach 1 - Maximum Use of Existing Devices		Approach 2 - RemoteTracker System		Approach 3 - Propeller Metering Program	
	With Gray Lodge Project	Without Gray Lodge Project	With Gray Lodge Project	Without Gray Lodge Project	With Gray Lodge Project	Without Gray Lodge Project
Initial Capital	$1,501,146	$1,713,538	$1,147,810	$1,360,202	$2,403,455	$2,615,848
Annualized Capital	$103,320	$116,016	$91,777	$104,473	$179,751	$192,447
Annualized Maintenance	$71,207		$70,999		$153,075	
Annualized Capital and Maintenance	**$174,527**	**$187,223**	**$162,776**	**$175,472**	**$332,826**	**$345,522**

ES-1.6 Corrective Action Plan

At a special, scheduled meeting on January 4, 2013, the BWGWD Board considered this report and the customer delivery measurement options presented herein. By unanimous vote, the Board accepted the report and adopted measurement Approach 2 - RemoteTracker System as the District's preferred approach for implementing a customer delivery measurement program. The program is intended to comply with the measurement accuracy standards specified in CCR 23 §597 and to be capable of supporting implementation of a water rate structure based at least in part on the volume of water delivered. Such a rate structure remains to be designed and adopted by the Board in the future.

Approach 2 has an estimated capital cost of $1,147,810 assuming that the Gray Lodge water conveyance project is implemented, or a cost of $1,360,202, if the Gray Lodge project does not proceed. Recognizing that these capital improvement costs are relatively large in comparison to the District's current revenue and operating budgets, the Board also unanimously agreed that the program will be implemented on a "pay-as-you-go" basis as discretionary revenues above operating and maintenance costs become available.

1.0 Introduction

1.1 Biggs-West Gridley Water District

Biggs-West Gridley Water District (District or BWGWD) is located in the Sacramento Valley in southern Butte County, Northern California. The District operates and maintains a canal and lateral distribution system that supplies water to roughly 32,000 acres. The primary crop grown within the District is rice. BWGWD's service area also includes portions of the Gray Lodge Wildlife Management Area. The District holds pre-1914 water rights to Feather River water in conjunction with three other districts that make up the Joint Water Districts Board (Richvale Irrigation District, Butte Water District and Sutter Extension Water District). Figure 1 shows the District's boundary, laterals, drains and turnouts.

1.2 Existing Measurement Practices

The large majority of the District's service area is planted to rice. There are essentially two different water delivery flow rates associated with irrigating a rice field: flood-up and maintenance. During flood-up, the goal is to quickly establish ponded water on the field. Flood-up deliveries typically range from 10 to 25 cubic feet per second (cfs), and can last from hours to days depending on field size and other factors. Once a rice field is flooded to the desired depth, the flow is decreased to a maintenance flow rate. Depending on field size, maintenance deliveries typically range from 1 to 6 cfs, and last for several weeks. During the maintenance period, fields may be drained and re-flooded one or more times for purposes of applying herbicides. The same delivery infrastructure is used to deliver both flood-up and maintenance flows.

Rice cultivation primarily occurs in river basin flood plains with very flat topography, resulting in small (or "low") "heads" (water surface elevation differences) between supply canals and the fields receiving water deliveries. Low heads make certain measurement devices unusable and can cause high measurement error. Measurement devices that are affected by low head include weirs, flumes, and orifices. Additionally, large ranges in delivery flow rates (e.g., 1 cfs during maintenance to 25 cfs during flood-up; see discussion above) pose challenges to certain measurement devices.

Due to these unique characteristics and measurement challenges associated with rice water delivery, farm turnout measurement has evolved differently in BWGWD (and in most other rice-dominated water suppliers) as compared to some other suppliers in California. Historically, the District's canal system has been operated based on the management of canal water levels (or pools). With canal water levels held at targeted elevations, certain field-specific gate settings will deliver the necessary rice flood up and maintenance flows. The field-specific gate settings have been determined from years of experience and have been calibrated to deliver sufficient water without causing excessive tailwater. Operating in this manner, appropriate amounts of water are delivered to rice fields without the need to measure delivery rates or volumes. In summary, the operation consists of setting and adjusting turnout gate opening as needed to maintain desired field conditions and adjusting water deliveries into canals as needed to

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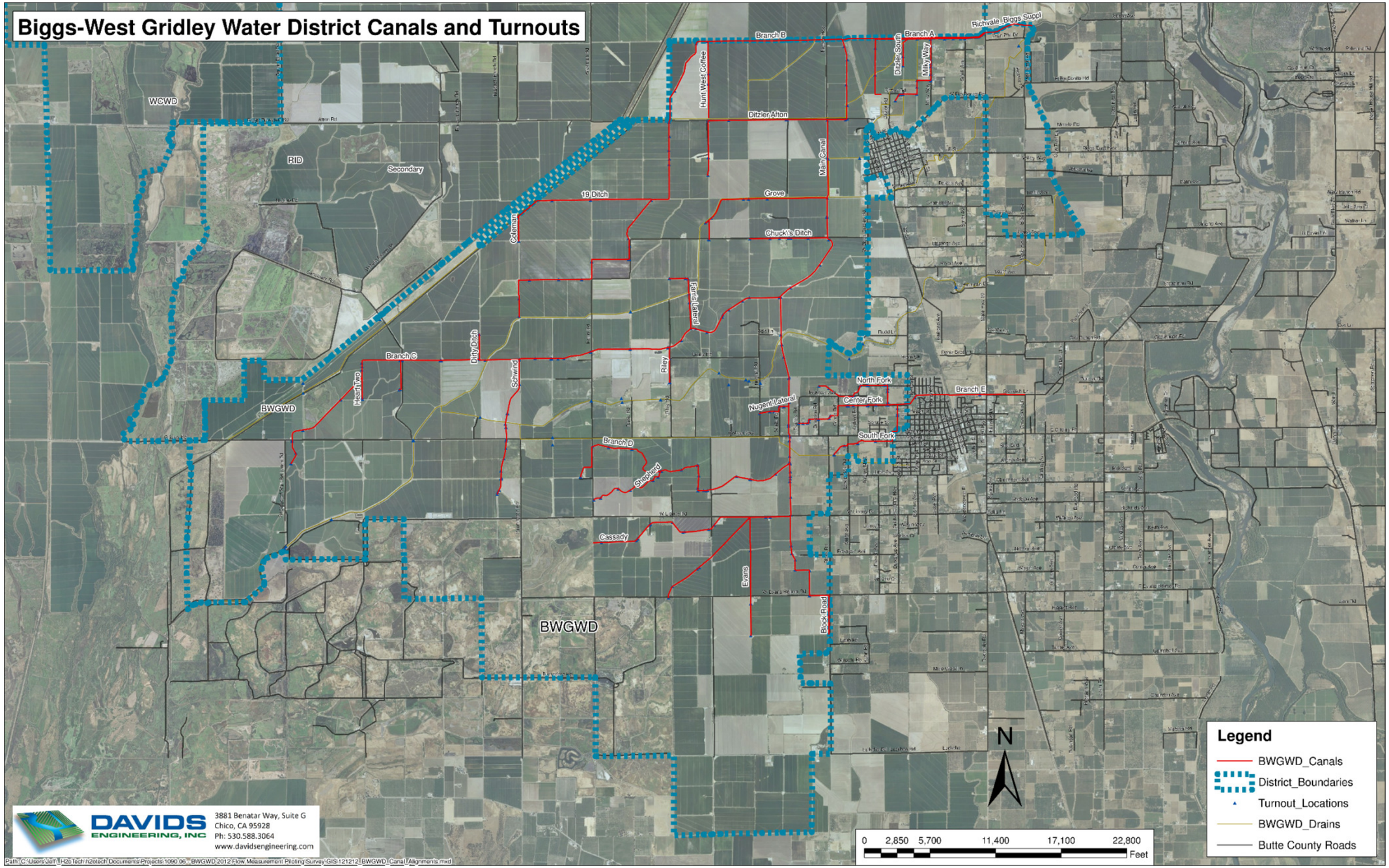

Figure 1. Biggs-West Gridley Water District Map Overview

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maintain targeted water levels. Flow adjustments are made based on approximations and rules of thumb, and there has been no need to measure water precisely to achieve "good" water management, provided that field tailwater and canal spills are held within reasonable limits.

1.3 SBx7-7 (CCR 23 §597) Overview

The Comprehensive Water Package passed by the California State legislature in November 2009 consists of four policy bills and an $11.14 billion water bond. One of the policy bills (Senate Bill x7-7 or SBx7-7) addresses both urban and agricultural water conservation and, with respect to agriculture, includes new mandates regarding the accuracy of customer delivery measurement, applicable to agricultural water suppliers serving more than 25,000 acres. BWGWD serves more than 25,000 acres and therefore is an agricultural water supplier subject to the new regulation.

The California Department of Water Resources (DWR) was responsible for developing and adopting regulations pursuant to SBx7-7. The rule making process was formally launched during the latter half of 2010 and first half of 2011. DWR developed the draft regulation with the input and involvement of an Agricultural Stakeholder Committee comprised primarily of staff members from agricultural water suppliers and environmental advocacy organizations, plus some academics and consultants. On October 19, 2011, the Office of Administrative Law (OAL) disapproved the proposed regulations because they failed to comply with the clarity, consistency and necessity standards contained in Government Code section 11349.1, and DWR failed to adequately summarize and respond to each comment made regarding the proposed action, including comments of BWGWD. Ultimately, after a number of revisions, OAL approved DWR's agricultural water measurement regulations as California Code of Regulations Title 23 Division 2 Chapter 5.1 Article 2 Section 597 et seq. (CCR 23 §597) on July 11, 2012.

CCR 23 §597 requires that, on or before July 31, 2012, agricultural water suppliers subject to the law shall measure the volume of water delivered to customers with sufficient accuracy to:

- Enable reporting of aggregated farm-gate delivery data to the State and
- Adopt a pricing structure based at least in part on the quantity of water delivered.

CCR 23 §597 requires that existing farm turnouts[1] like those in the District have a measurement accuracy of ±12 percent by volume, meaning that the measured volume of water delivered at each farm-gate (i.e. turnout) must be no greater than 12 percent more, or 12 percent less, than the actual volume delivered. Additionally, any new or replacement measurement devices installed must be accurate to within:

- ±5 percent by volume in the laboratory if using a laboratory certification;
- ±10 percent by volume in the field if using a non-laboratory certification

[1] The use of "farm turnout" in this document is synonymous with "farm-gate" and "customer delivery point" utilized in CCR 23 §597.

The regulation requires that an accuracy certification be performed by either: (1) field testing of a random and statistically representative sample of existing farm turnouts, (2) field inspections and analysis of every existing farm turnout, with the testing or inspections documented by a registered engineer, or (3) a laboratory certification.

1.4 Purpose and Structure of Report

The purpose of this document is to summarize the activities and analysis performed by Davids Engineering during 2012 in support of the District's evaluation of options for customer delivery measurement that are compliant with CCR 23 §597. The evaluation of options was comprised of the following three tasks:

1. Preparing an inventory of BWGWD delivery gates, including establishing GPS coordinates and critical physical characteristics, including turnout pipe size, gate type and available head.

2. Pilot testing of RemoteTracker operation, and developing and testing measurement data collection and customer billing processes during the 2012 irrigation season.

3. Evaluating alternative measurement devices and compliance approaches, including estimated capital costs.

This report documents the work completed according to the three tasks described above. The report is organized into the following five sections:

- **1.0 Introduction** - Provides information about BWGWD, its existing measurement practices, CCR 23 §597 and the purpose of this report
- **2.0 Farm Turnout Inventory** - Summarizes the findings of the farm turnout inventory
- **3.0 Alternative Measurement Devices** - Presents overviews of four measurement devices, including their respective abilities to meet the accuracy mandates of CCR 23 §597
- **4.0 Alternative Measurement Approaches** - Describes three measurement approaches for District-wide measurement based on the four measurement devices described in Section 3.0
- **5.0 Cost Estimates** - Provides reconnaissance-level capital cost estimates for the three measurement approaches developed in Section 4.0
- **6.0 Corrective Action Plan** - Presents basic overview of BWGWD's selection of a preferred measurement approach

2.0 Farm Turnout Inventory

2.1 Inventory Data Collection

An inventory was performed during the 2012 irrigation season to identify all existing farm turnouts in the District and to characterize each farm turnout with respect to factors related to application of the four possible measurement devices evaluated. The following conditions/attributes were determined for each farm turnout:

- Turnout operation status (active/inactive)
- Crop currently being served (rice or other)
- Turnout type defined by unique combinations of certain conditions on the District side and farm side of the turnout
- Turnout gate manufacturer, configuration (square or round) and dimensions
- Structure/culvert/pipeline dimensions (lengths and diameters of critical hydraulic dimensions)
- Critical elevations (canal high water, field, field high water, top of structure)

Additionally, photographs were recorded of each farm turnout, focused on the key attributes noted above.

Figure 2 shows the form used to record inventory measurements and observations at each farm turnout.

Field Served by Turnout:		Gate Brand:		Bench Mark:	
Date:		Gate Type:		U/S WSE:	
Time In/Out:	/	Gate Size:		U/S HWM:	
District:		Closed/Dead Stem	/	D/S WSE:	
Canal:		Weir Length:		D/S HWM:	
Barcode SKU:		Meter Type:		D/S Top Of Box:	
Pipe Inner Diameter:		Photos:	U/S D/S	Crown:	
Pipe Length/Type:	/	Flow Rate:			
Site Type:	Gate / Pump	Totalizer:			

Notes:

Figure 2. Standard Farm Turnout Inventory Form

A database was developed to contain and enable convenient access to and analysis of the inventory data (e.g. photographs, critical elevations, crop type, etc.). The database was used to develop a Google Earth user interface that retrieves a tabular summary of a site's attributes and photographs to be viewed on-screen when the site is selected. Figure 3 shows a screen shot of several turnouts on the Ashley and Ditzler Afton Canals near Afton Road and Figure 4 shows a sample of the site detail accessed via the Google Earth user interface.

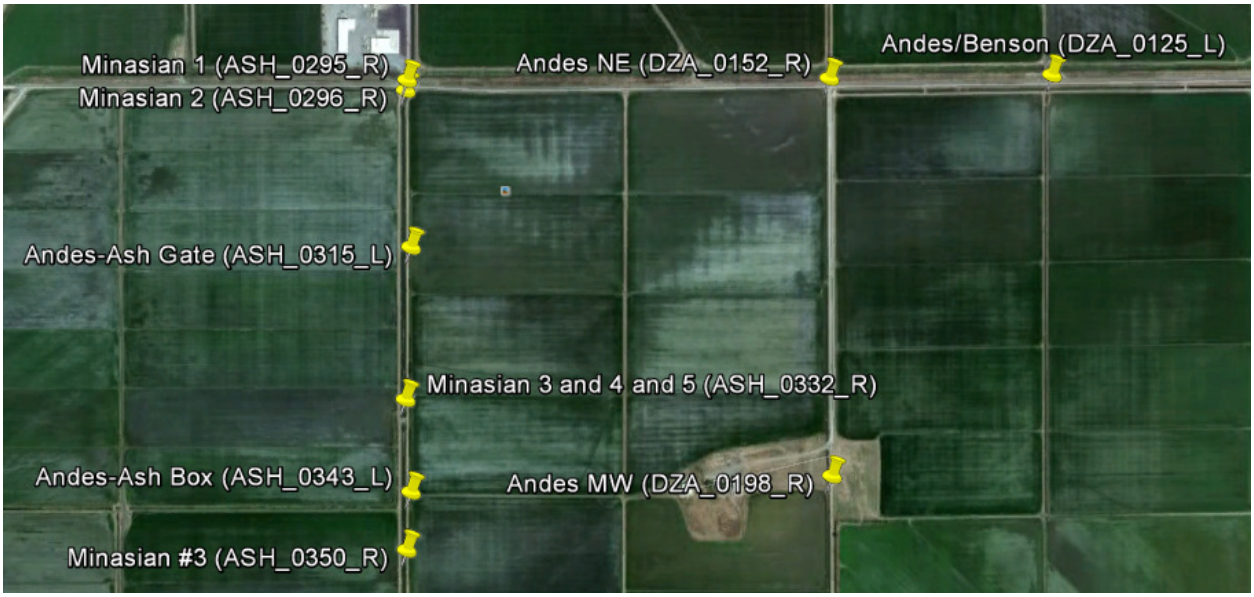

Figure 3. Google Earth Turnout Inventory Overview of the Ashley Canal near Afton Road

Minasian 3 and 4 and 5 (ASH_0332_R)

C:\Turnout_Inventory_BWGWD\Photos\Ashley (ASH)ASH_0332_R

Common Name:	Minasian 3 and 4 and 5
Site ID:	ASH_0332_R
Canal:	Ashley (ASH)
Ride:	Chuck
Crop:	Rice
Site Type:	Gate
Measurement Method:	Manual
Gate Brand:	Gator Gates
Gate Type:	Rectangular
Gate Size (in):	30
Pipe Type:	Concrete
Pipe Inner Diameter (ft):	
Pipe Length (ft):	24
Weir Length (ft):	
Available Head (ft):	1.61

Figure 4. Sample of Inventory Detail Accessed via the Google Earth User Interface

2.2 Farm Turnout Inventory Summary

Figure 5 provides a summary of the farm turnout inventory. A total of 359 farm turnouts were identified during the inventory. Of the total of 359 farm turnouts, 329 are served by supply canals and 30 are served by drainage channels (drains). Of the 329 farm turnouts served by supply canals, 321 turnouts operate by gravity and 8 are pumped. All 30 farm turnouts served by drains are pumped. Of the 321 gravity farm turnouts served by supply canals, 279 are controlled by orifice gates (gates) and 42 are controlled by other means (e.g. alfalfa valves, weir structures, or other). Just 29 of the 279 gate-

controlled gravity farm turnouts have weir boxes. None of the 42 turnouts from supply canals controlled by other means have weir boxes.

As part of the Gray Lodge Wildlife Area Water Supply Project[2] (Gray Lodge Project), the District will be replacing, or retrofitting in some cases, a total of 95 gravity farm turnouts along the Upper Belding, Traynor, Rising River, Lower Belding, Schwind and Cassady laterals. This represents about 30 percent of the District's 321 canal-fed gravity turnouts. The farm turnout (and other) modifications have been designed, but not yet constructed; thus, the information summarized below does not account for the improvements that will eventually be made to the 95 affected farm turnouts.

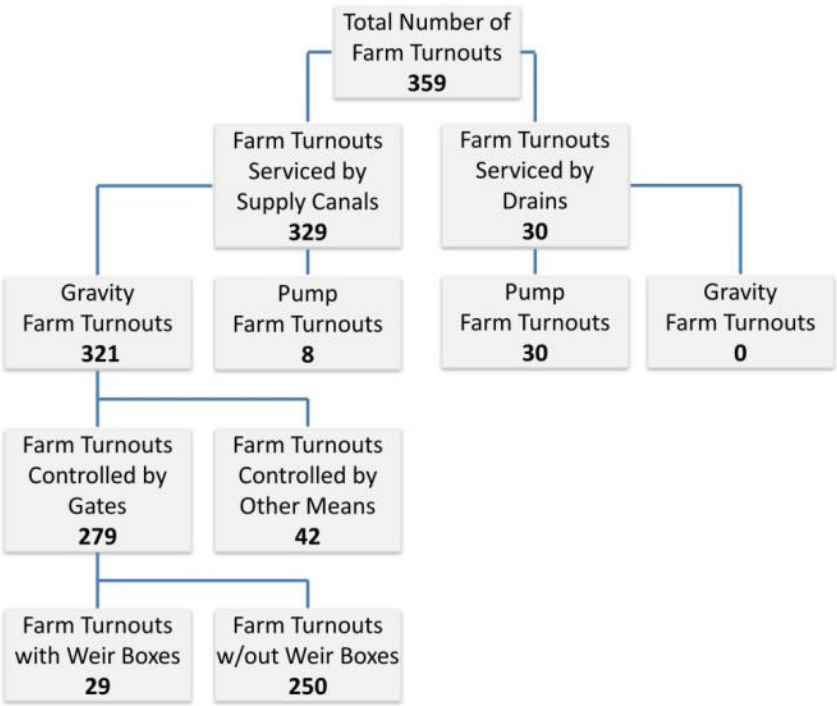

Figure 5. Farm Turnout Inventory Summary

2.3 Crop Types

Table 1 summarizes the District's farm turnouts according to the type of crop served during the 2012 irrigation season. Of the total 359 turnouts, 290 (or 81 percent) serve rice fields. The next most common crop types are orchards and pasture, which each account for 5 percent of the total turnout count. Additional crops include row crops, alfalfa and unknown crops.

[2] The District is presently implementing this project under a cooperative agreement with the U.S. Bureau of Reclamation (Reclamation). The project generally consists of canal widening and structure replacement along certain reaches of the District's water distribution that supply water to the wildlife area. The purpose of the project is to provide additional water to the wildlife area, made available by Reclamation, above the supplies received from the District and other sources.

Table 1. Turnout Distribution by Type of Crop Served during 2012

Crop Type							
	Rice	Orchard	Pasture	Row Crop	alfalfa	Unknown[3]	Total
Count	290	19	17	2	1	30	359

2.4 Farm Turnout Pipe Lengths

Farm turnout pipe lengths vary from less than 10 feet to over 70 feet. Table 2 provides a summary of the pipe lengths in the District.

Table 2. Summary of Pipe Lengths

Pipe Length								
	<10'	10'-20'	20'-30'	30'-50'	50'-70'	>70'	Unknown	Total
Count	8	77	113	53	21	16	71	359

2.5 Orifice Gate Characteristics

Table 3 summarizes the characteristics of the 279 existing orifice gates inventoried during the 2012 irrigation season. The dominant gate brand is Waterman Industries, accounting for 166 gates (59%). 122 farm turnouts have circular orifice gates, while 157 have rectangular orifice gates. The most common gate size (based on gate frame widths) is 24 inches (110 in total), followed by 14 to 16 inch and 18 inch (69 and 40 gates, respectively).

Table 3. Orifice Gate Inventory Summary

Gate Brand								
	Water-man	Armco	Mech. Assc.	Gator Gates	Fresno Valves	Generic[4]		Total
Count	166	25	13	15	2	58		279
Gate Type								
	Circular	Rectang-ular						Total
Count	122	157						279
Gate Dimensions								
	<14"	14"-16"	18"	20"	24"	26"-30"	26"-48"	Total
Count	19	69	40	6	110	18	17	279

[3] The 30 pump farm turnouts serviced by drains were inventoried via satellite imagery with District personnel. The crop types for these 30 farm turnouts are unknown because the sites were not being field inspected.
[4] 'Generic' gate brand indicates that there were no specific markings on the orifice gate that identified the gate manufacturer.

2.6 Turnout Head

Where possible, the farm turnout head (difference in typical upstream and downstream water surface elevations) was surveyed. The typical canal operating water level was used for the upstream level and the high water mark on the field side was used for the downstream level. If no downstream high water mark was evident, the downstream water level for rice fields was estimated to be six inches higher than the field elevation. Figure 6 displays a histogram of heads for the 321 gravity farm turnouts served by supply canals.

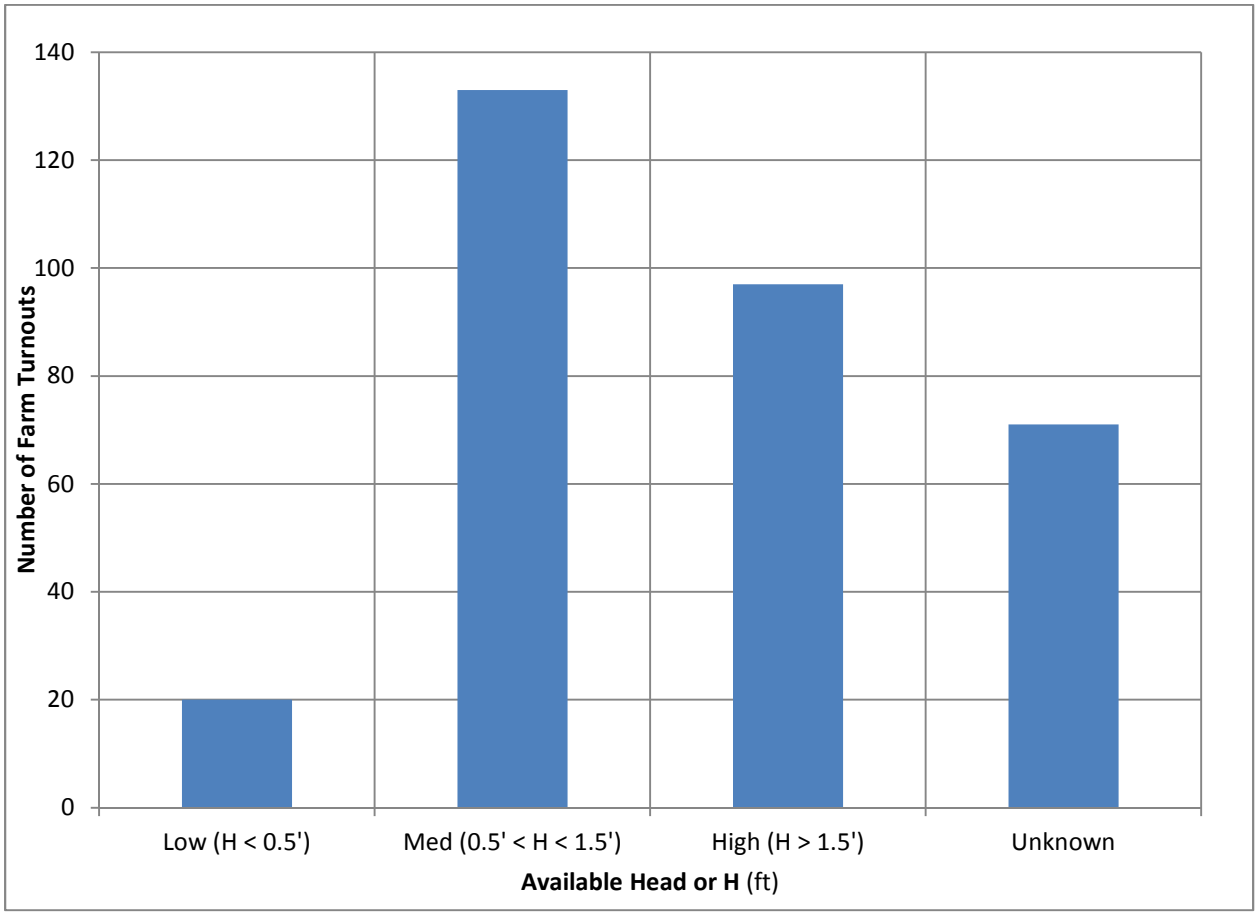

Figure 6. Turnout Head[5]

The gravity farm turnouts are classified into basic categories: low head (less than 0.5 feet), medium head (between 0.5 and 1.5 feet) and high head (greater than 1.5 feet). There are 20 low head gravity farm turnouts, 133 medium head gravity farm turnouts and 97 high head gravity farm turnouts. 71 gravity farm turnouts have an unknown amount head[6].

[5] Includes heads for only the 321 gravity farm turnouts served by supply canals.

[6] Farm turnout head was categorized as "unknown" category if the upstream or downstream water level could not be quantified with sufficient accuracy due to lack of physical access or lack of physical evidence (e.g. water stains) of typical operating water levels.

3.0 Alternative Measurement Devices

Four measurement devices were evaluated for potential application to achieve compliance with the CCR 23 §597 accuracy mandates. Although presently not used for measurement (see Section 1.2), the existing farm turnout gates could be used for measurement based on the submerged orifice principle. Alternatively, the weir boxes that have been installed at 29 turnout pipe outlets could be used for measurement based on the weir principle. These two existing devices are described further in Sections 3.1 and 3.2 below. In addition to the existing orifice gates and weir boxes, two new measurement devices were considered for compliance with CCR 23 §597, including the RemoteTracker system and propeller meters. These devices are discussed in Sections 3.3 and 3.4 below.

The discussion of each device concludes with an assessment of the device's ability to comply with the volumetric accuracy mandates of CCR 23 §597. With the exception of propeller meters, which would be permanently installed at each farm turnout, orifice gates, weir boxes and the RemoteTracker do not provide continuous records of flow rate over time; rather they provide "spot" measurements of flow rate at specific points in time. Accurate determinations of delivery volumes can be made with spot flow rate measurements if (1) the spot flow rate measurement and the actual average flow rate during the delivery event are similar and (2) accurate determinations of delivery durations are made. In Biggs-West Gridley Water District, canal water levels are controlled by a variety of structures, including standard check structures and orifice gates. However, farm-gate deliveries (i.e. the "delivery points" as defined by CCR 23 §597.2(a)(6)) are predominantly made through orifice gates. Delivery flow rates through orifice gates will vary if fluctuations occur in canal water levels[7] (i.e. upstream) or on-farm water levels (i.e. downstream). Therefore, an understanding of water level fluctuations is required to characterize the relationship between spot flow rate measurements and the actual average flow rates over time.

Analysis of continuous water level data recorded between 2004 and 2006 from eight sites on BWGWD canals indicates that the effects of fluctuating water levels on the accuracy of volumetric measurements developed from "spot" flow measurements are negligible. A similar analysis performed by the California Polytechnic State University San Luis Obispo Irrigation Training and Research Center reached a similar conclusion (Burt and Geer 2012).

Therefore, the discussion of compliance with CCR 23 §597 focuses on each device's ability to accurately measurement flow rate, even though the regulation is for volumetric accuracy.

[7] Canal water levels fluctuate because it is not possible to set control gates perfectly as agricultural water demands change during an irrigation season.

3.1 Orifice Gates

3.1.1 Overview

Discharge through a submerged orifice gate (example shown in Figure 7) can be computed with the Bernoulli Equation (Equation 1), where C is an empirical coefficient used to account for energy loss (i.e. entrance/exit losses through the orifice), flow contraction (i.e. vena contracta), and velocity of approach

Figure 7. Typical Orifice Gate Farm Turnout on the Green Lateral (GRN_0620_L)

(Water Measurement Manual (WMM) 2001; King 1963), A is the cross section flow area through the gate (dependent on gate opening), h is the head loss through the orifice and g is the gravitational constant.

$$Q = C * A * \sqrt{2 * g * h}$$ **(*Equation 1 – Lindeburg 2008)***

The difference between water surface elevations (WSE) upstream and downstream of the orifice gate indicate the head loss, and the flow area is determined from the gate size and the gate opening, which is indicated by the gate stem position. The stem position is the measured distance between the highest part of the gate 'lift nut' and the top of the gate stem. Dead-stem is defined as the stem position at the onset of flow when moving the gate from a closed to open position. Full-stem is defined as the stem

position when the gate is opened for operation. A term representing the actual gate opening called "good-stem" was then defined as the difference between full-stem and dead-stem (Equation 2).

$$Goodstem = (Fullstem) - (Deadstem)$$ **(*Equation 2*)**

"Good-stem" is used to calculate the actual area of the opening with the gate size and gate type (circular or rectangular) known.

3.1.2 Compliance with CCR 23 §597

Data from previous investigations (Davids Engineering 2012) indicates that orifice gates can measure within the CCR 23 §597 accuracy mandate for existing measurement devices (±12 percent) provided that:

- Gate-specific variable coefficients based on multiple measurements at each gate are developed and
- Sufficient headloss occurs through the orifice gate to facilitate differential head measurements with low relative uncertainty (i.e. gates not operating near fully open position leading to minimal headloss through the gate and high relative uncertainties in water level measurements)

Results of an evaluation of orifice coefficients are summarized below in Table 4, including indication of whether the coefficient is adequate for meeting the ±12 percent accuracy mandate for existing devices. Using the standard "rating table" coefficients, 27 percent of the orifice measurements fall within ±12 percent of the verification measurements. Using a "District-wide constant" coefficient, just 11 percent of the orifice measurements fall within ±12 percent of the verification measurements. Using a "gate-specific constant" coefficient, 25 percent of the orifice measurements fall within ±12 percent of the verification measurements. Finally, using a "gate-specific variable" coefficient, 96 percent of the orifice measurements fall within ±12 percent of the verification measurements. Only "gate-specific variable" coefficients ensure that at least 75 percent of the sample falls within ±12 percent of the verification measurements. If orifice gates were used for measurement, every gate would need to have a customized variable coefficient developed for it using field testing procedures.

Hydraulic analysis of a 24 inch orifice gate indicates that, if a 12 cubic foot per second[8] (cfs) flood flow is desired, a minimum of 0.5 feet of head is required[9]. Based on this criterion, and the survey information discussed in Section 2.6, 172 of the 321 gravity farm turnouts (54 percent) have enough head to measure with an orifice gate.

[8] 12 cfs is used throughout the remainder of this document as the minimum acceptable delivery flow rate for complaint devices.

[9] This analysis assumes that a 0.3 foot headloss through the orifice gate is required to facilitate differential head measurements with low relative uncertainty. The additional 0.2 feet of head is required for major and minor head losses between the orifice gate and the field.

Table 4. Overview of Orifice Gate Measurements with Different Methods of Calculating Orifice Coefficient

Basis for Coefficient	Meets SBx7-7 ±12 Percent Accuracy?	% of Farm Turnouts Within ±12 Percent
Standard "rating table" coefficients	No	27%
District-wide constant coefficient derived from measurements at a sample of gates	No	11%
Gate-specific constant coefficients based on multiple measurements at each gate	No	25%
Gate-specific variable coefficients based on multiple measurements at each gate	Yes	96%

3.2 Weirs

3.2.1 Overview

Weirs installed in boxes placed at the turnout pipe outlets operate as standard suppressed rectangular weirs because the weir crest occupies the full box width (i.e., there is no flow contraction) (Figure 8). The Francis equation, which was empirically derived in 1883 to calculate flow over a standard suppressed rectangular weir is shown in Equation 3, where (L) is the length of the weir in feet (ft), and (h) is the height of the fluid over the crest in feet.

$$Q = 3.33\, L\, h^{3/2}$$ ***(Equation 3 – WMM 2001)***

The coefficient of discharge (3.33) was obtained by a set of experiments to correlate the head above the crest with the amount of flow passing over the weir (WMM 2001). For this equation to be most accurate, certain conditions must be met. The weir crest elevation should be at least 0.2 ft above the field WSE so that a free fall occurs (WMM 2001). If the elevation difference is less than 0.2 ft, the free fall of the water may be affected by "backwater" effects and the accuracy of the measurement may be decreased. Additionally, when h is less than 0.2 ft or greater than one-third the crest length, acquiring a precise head measurement becomes challenging and measurement accuracy may be compromised (WMM 2001).

Figure 8. Typical Weir Box on the Ashley Canal near Afton Road

3.2.2 Compliance with CCR 23 §597

Data from previous field investigations (Davids Engineering 2012) indicates that weirs can measure within the CCR 23 §597 accuracy mandate for existing measurement devices (±12 percent) provided that:

- Sufficient head (drop) is available between the canal water level and field water level
- Leakage through weir boards is stopped (or accounted for)

Hydraulic analysis of a four foot wide weir box indicates that, if a 12 cubic foot per second (cfs) flood flow is desired, a minimum of 1.5 feet of head is required[10]. Based on this criterion, and the survey information discussed in Section 2.6, 123 of the 321 gravity farm turnouts (38 percent) have enough head to measure with a weir.

[10] Roughly 1.0 foot of head over a four foot weir produces 12 cfs. Additionally, the analysis assumes a 0.3 foot headloss through the orifice gate is required for the delivery to remain in 'orifice control', plus 0.2 feet of headloss for major and minor losses between the orifice gate and the weir box.

3.3 RemoteTracker System

3.3.1 Overview

The RemoteTracker is an integrated turnout flow measurement, data management and volumetric accounting system developed by H2oTech[11] specifically for agricultural water suppliers. The RemoteTracker system is comprised of (1) a wireless water velocity sensor, (2) a ruggedized tablet PC carried in the operator's vehicle and (3) a database residing on a file server connected to the tablet PC via a cellular internet connection. The user interface on the tablet PC enables operators to view real time flow data from the wirelessly controlled water velocity sensor via a Bluetooth radio connection while adjusting flows at the turnout gate. The RemoteTracker calculates flow rate with Equation 4.

$$Q = C_{RT} * V_D * A \qquad \textbf{\textit{(Equation 4)}}$$

Where:

- C_{RT}: RemoteTracker velocity coefficient
- V_D: Velocity measured by the wireless water velocity sensor
- A: Cross-section flow area

The key to pipe flow measurement using the RemoteTracker is the consistent relationship between a single velocity measurement at the center of the pipe and the average pipe flow velocity shown derived from 146 measurements of center and mean pipe velocity (Figure 9). Based on this relationship, and with the pipe diameter and cross sectional flow area known, the single point velocity can be accurately and reliably correlated with flow rate.

[11] H2oTech is a company based in Chico, California that focuses on the development of innovative technologies to solve water management challenges.

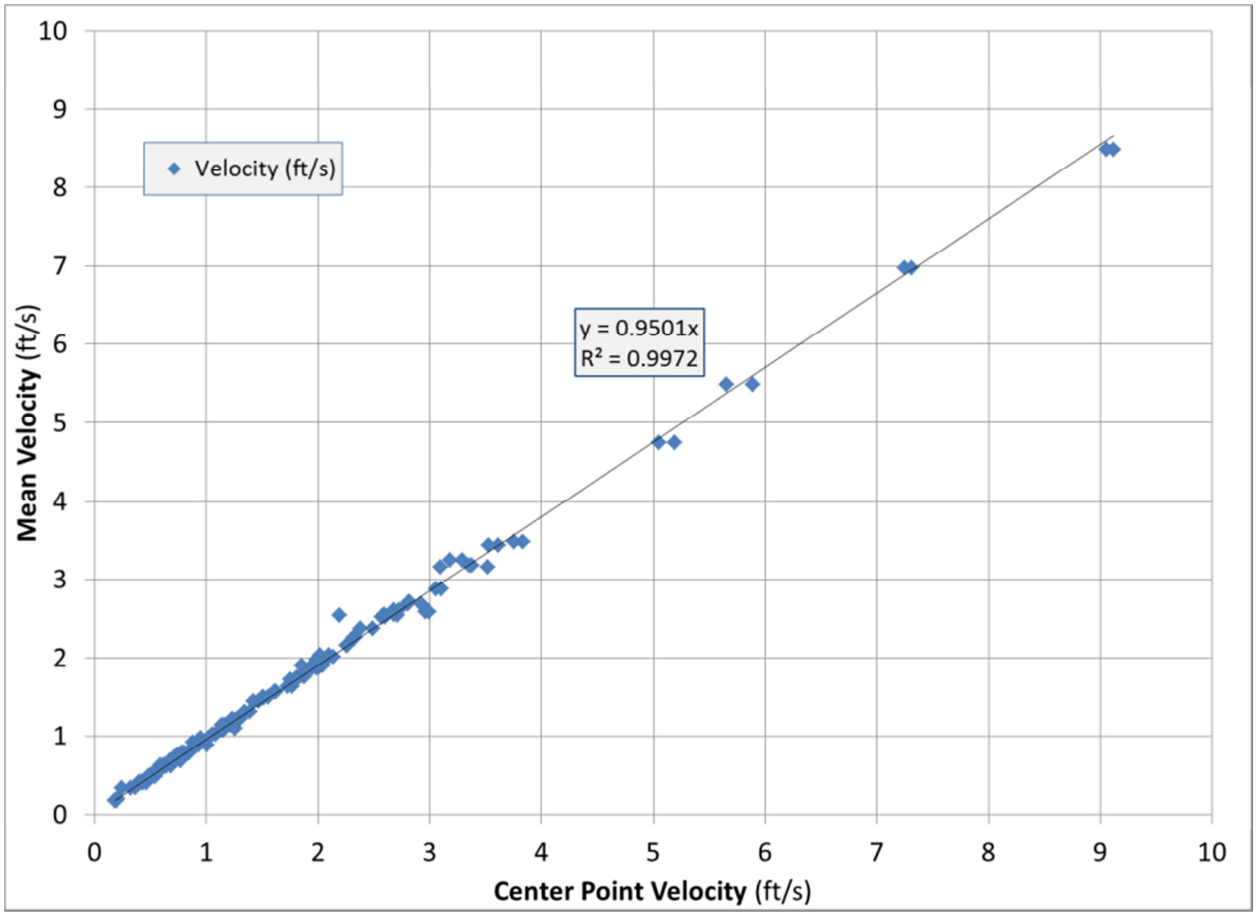

Figure 9. Relationship between Average and Center Point Pipe Flow Velocity

As for weirs and orifice gates, full pipe flow is required for the RemoteTracker to measure correctly. Therefore, a weir box is needed at each turnout to ensure full pipe flow as well as to accommodate the mounting bracket to hold the wireless water velocity sensor, during deployment, so that the sample volume is near the center of the pipe. Figure 10 shows the RemoteTracker wireless water velocity sensor deployed in a weir box.

Figure 10. RemoteTracker Wireless Water Velocity Sensor Deployed in Weir Box

A more detailed explanation of the RemoteTracker system, including results of laboratory and field testing, is included in Sections A-2.0 and A-3.0 of Appendix A.

3.3.2 Compliance with CCR 23 §597

The RemoteTracker system is compliant with the volumetric accuracy mandates of CCR 23 §597. See Appendix A for a laboratory based volumetric accuracy certification of the RemoteTracker system. The RemoteTracker system can provide accurate flow data over all farm turnout head ranges.

3.4 Propeller Meters

3.4.1 Overview

Using propellers meters for farm turnout measurement involves permanently installing a propeller meter device at each farm turnout[12]. Propeller meters have a propeller that is placed in the outfall of the farm turnout pipe. The propeller is rotated by water flowing in the pipe and is mechanically or

[12] Because of the heaviness of propeller meters and the need to match meter size to the different turnout pipe sizes, it is considered impractical to deploy propeller meters temporarily for spot flow checks in the same manner that the RemoteTracker is deployed. Instead propeller meters would be permanently deployed at each turnout for the duration of each irrigation season.

electronically coupled with a display and recording device. The rate of rotation is directly proportional to velocity of the water in the pipe. With the pipe diameter and cross-sectional area known, flow rate can be calculated as the product of velocity and area. Propeller meters typically measure flow rate continuously and totalize the delivery volume. The display typically indicates instantaneous flow rate and cumulative volume delivered. For deployment in BWGWD, propeller meters would require the same farm turnout infrastructure as the RemoteTracker. An orifice gate would be required at the farm turnout inlet to control flow and a weir box would be required at the turnout pipe outlet to (1) keep the pipe full and (2) provide a place to mount the propeller meter.

3.4.2 Compliance with CCR 23 §597

Laboratory certifications of flow measurement accuracy are available for most commercially available propeller meters. Since propeller meters are permanently installed devices, volumetric accuracy is the same as flow rate accuracy. Therefore, propeller meters are compliant with the volumetric accuracy mandates of CCR 23 §597. Propeller meters can provide accurate flow data over all farm turnout head ranges.

4.0 Alternative Measurement Approaches

As discussed in Sections 3.1.2 and 3.2.2, orifice gates and weir boxes require a minimum of 0.5 feet and 1.5 feet of head respectively to measure a minimum of 12 cfs. To facilitate the development of measurement approaches, all farm turnouts within the District were classified into one of four farm turnout categories[13]:

1. Low Head Gravity (i.e. head less than 0.5 feet),
2. Medium Head Gravity (i.e. head between 0.5 and 1.5 feet),
3. High Head Gravity (i.e. head greater than 1.5 feet) and
4. Pump (i.e. water supplied to fields via pumps).

Table 5 presents a summary of three measurement approaches considered to be potentially viable for the District to comply with CCR 23 §597. Table 5 indicates the number of turnouts falling in each category and, for each approach, the measurement device that would be used for each category. The three approaches are discussed in greater detail in Sections 4.1 through 4.3. None of the measurement devices discussed in Section 3 can be utilized to measure pump deliveries. Therefore, all three approaches include the use of totalizing flow meters at the 38 pump deliveries within the District.

Table 5. Measurement Approach Summary

Farm Turnout Category	Count of Farm Turnout Categories	Measurement Devices		
		Approach 1 - Maximum Use of Existing Devices	Approach 2 - RemoteTracker System	Approach 3 - Propeller Metering Program
Low Head Gravity (H < 0.5 feet)	**26**	Propeller Meters	RemoteTracker System	Propeller Meters
Medium Head Gravity (0.5' < H < 1.5')	**172**	Orifice Gates		
High Head Gravity (H > 1.5')	**123**	Weir Boxes		
Pump	**38**	Totalizing Flow Meters	Totalizing Flow Meters	Totalizing Flow Meters
Total	**359**			

[13] Farm turnouts with unknown heads were distributed between the three gravity farm turnout categories in the same proportion as the known farm turnouts. In other words, of the turnouts with known heads, 8 percent were low head, 53 percent were medium head and 39 percent were high head. These percentages were then used to distribute the 71 unknown gravity farm turnouts among the three gravity farm turnout categories.

Table 6 summarizes the different levels of turnout improvement needed for each of the farm turnout categories, and the number of turnouts in each improvement level. These farm turnout counts are utilized in Section 5.0 to develop capital cost estimates for each measurement approach. All measurement approaches require gravity farm turnouts to have an orifice gate and a weir box. All pump farm turnouts require a totalizing flow meter. The classifications have been developed to be mutually exclusive so that each farm turnout only corresponds with one improvement classification within the table, which facilitates the ability to sum the number of farm turnouts in each row to develop the total number or farm turnouts in each farm turnout category. The Gray Lodge project will be replacing or retrofitting a number of gravity farm turnouts in each classification; therefore, a 'Gray Lodge' classification is necessary to avoid double counting. The farm turnout improvement classifications include:

- **Requires Orifice Gate and Weir Box** - existing gravity farm turnout has neither an orifice gate or a weir box
- **Requires Orifice Gate Only** - existing gravity farm turnout has a weir box, but no orifice gate
- **Requires Weir Box Only** - existing gravity farm turnout has a orifice gate, but no weir box
- **Requires No Improvements** - existing gravity farm turnout has an orifice gate and a weir box
- **Improvements by Gray Lodge Project** - improvements to existing farm turnout to be made by others
- **Requires Totalizing Flow Meter** - existing pump farm turnout has no measurement device

Table 6. Farm Turnout Improvement Classification Count Summary

Farm Turnout Category	Farm Turnout Improvement Classification Counts						Sum
	Requires Orifice Gate and Weir Box	Requires Orifice Gate Only	Requires Weir Box Only	Requires No Improvements	Improvements by Gray Lodge Project	Requires Totalizing Flow Meter	
Low Head Gravity (H < 0.5 feet)	10	0	11	4	1	n/a	26
Medium Head Gravity (0.5' < H < 1.5')	22	0	95	12	43	n/a	172
High Head Gravity (H > 1.5'	7	0	60	5	51	n/a	123
Pump	n/a	n/a	n/a	0	0	38	38
Totals	39	0	166	21	95	38	**359**

4.1 Approach 1 - Maximum Use of Existing Devices

Approach 1 is based on maximizing the use of existing measurement devices; however, neither of the two existing measurement devices (i.e. orifice gates and weir boxes) alone unconditionally meets the volumetric accuracy mandates of CCR 23 §597 across all gravity farm turnouts. Therefore, to achieve maximum use of existing devices, a hybrid approach involving multiple measurement devices is necessary. Approach 1 utilizes weir boxes for high head gravity farm turnouts and orifice gates for medium head gravity farm turnouts. Propeller meters, a new device, would be used for low head gravity farm turnouts because neither gates nor weirs work under low head conditions. Measurement of the 38 pump deliveries in the District requires the installation of totalizing flow meters.

4.2 Approach 2 - RemoteTracker System

Approach 2 involves the use of the RemoteTracker system at all gravity farm turnout categories (i.e. high head gravity, medium head and low head gravity farm turnouts). Measurement of the 38 pump deliveries in the District requires the installation of totalizing flow meters.

4.3 Approach 3 - Propeller Metering Program

Approach 3 involves the use of propeller meters at all gravity farm turnout categories (i.e. high head gravity, medium head and low head gravity farm turnouts). Measurement of the 38 pump deliveries in the District requires the installation of totalizing flow meters.

5.0 Reconnaissance Cost Estimates

BWGWD, along with other agricultural and urban water suppliers, filed a Test Claim with the Commission on State Mandates alleging that the Water Conservation Act constitutes a reimbursable state mandate. That Test Claim is pending before the Commission and it is anticipated that a hearing will be held in September, 2013, and a decision will be made shortly thereafter. BWGWD, along with other agricultural water suppliers, are in the process of filing a supplemental Test Claim challenging CCR 23 § 597. If the Test Claims are successful, BWGWD will be entitled to reimbursement of all direct and indirect costs of compliance with the Water Conservation Act and 23 CCR § 597, including initial and annualized capital and maintenance and operation costs of farm-gate measurement devices.

As part of the Gray Lodge Wildlife Area Water Supply Project (Gray Lodge Project), the District will be replacing, or retrofitting, a total of 95 gravity farm turnouts[14] along the Upper Belding, Traynor, Rising River, Lower Belding, Schwind and Cassady laterals. This represents about 30 percent of the District's 321 canal-fed gravity turnouts. The farm turnout (and other) modifications to be implemented under the project have not yet been constructed but have been designed to facilitate measurement with any of the four measurement devices evaluated (i.e. orifice gates, weirs, the RemoteTracker and propeller meters). Therefore, the cost estimates included herein do not include the capital costs for weir box and orifice gate installation at these 95 gravity farm turnouts because those costs will be borne by the Gray Lodge Project. The farm turnout inventory discussed in Section 2, however, does not account for the improvements that will eventually be made to the affected farm turnouts.

Table 7 provides reconnaissance-level (1) initial capital, (2) annualized capital and (3) annual maintenance cost estimates for full scale implementation of the three measurement approaches discussed in Section 4. Each approach lists two possible scenarios regarding the farm turnouts within the Gray Lodge project. The left column reflects the annualized capital and maintenance cost under the conditions that certain improvement requirements for farm turnouts within the Gray Lodge project will be covered by an entity other than the District. The right column reflects the annualized capital and maintenance cost for all improvements including the farm turnouts within the Gray Lodge project. The annualized maintenance costs are the same for both scenarios. The last row provides the annualized capital and maintenance cost estimates. Differences among the three approaches with respect to operation costs (primarily labor and transportation) are not considered significant; therefore they are not included. A five percent interest rate was used for all calculations.

Sections 5.1 through 5.3 below contain additional details regarding the capital cost estimates for the three alternative measurement programs evaluated. Each of the three alternative measurement approaches requires (1) a Water Information System (WIS) to store and process farm turnout delivery data and (2) the installation of totalizing flow meters on all pump deliveries. The measurement devices

[14] As summarized in Table 6, the Gray Lodge Project will be replacing or retrofitting one low head, 43 medium head and 51 high head gravity farm turnouts, for a total of 95 farm turnouts.

Table 7. Reconnaissance-Level Cost Estimates for Three Measurement Approaches

Cost Category	Measurement Program Cost Estimate					
	Approach 1 - Maximum Use of Existing Devices		Approach 2 - RemoteTracker System		Approach 3 - Propeller Metering Program	
	With Gray Lodge Project	Without Gray Lodge Project	With Gray Lodge Project	Without Gray Lodge Project	With Gray Lodge Project	Without Gray Lodge Project
Initial Capital	$1,501,146	$1,713,538	$1,147,810	$1,360,202	$2,403,455	$2,615,848
Annualized Capital	$103,320	$116,016	$91,777	$104,473	$179,751	$192,447
Annualized Maintenance	$71,207		$70,999		$153,075	
Annualized Capital and Maintenance	**$174,527**	**$187,223**	**$162,776**	**$175,472**	**$332,826**	**$345,522**

evaluated (i.e. gates, weirs, RemoteTracker and Propeller Meters) are designed for measurement of gravity deliveries, and are therefore unable to measure pump deliveries. Note that all cost estimates located in section 5.1 through 5.3 assume that improvements made to all turnouts within the Gray Lodge project will be covered by an entity other than the District. Appendix B provides additional information about the estimates for all unit costs, including the WIS and totalizing flow meters.

5.1 Approach 1 - Maximum Use of Existing Devices

Table 8 provides a cost summary for Approach 1, listing the necessary improvements, the number of farm turnouts that require the improvement and the expected life of the improvement.

Table 8. Approach 1 Cost Summary

#	Improvements	# of Sites Required	Unit cost	Initial Capital Sub-Total	Expected Life (years)	Annualized Sub-Total
1	Propeller Meter	26	$4,528	$117,733	20	$9,447
2	Orifice Gate	39	$5,017	$195,681	25	$13,884
3	Differential Head Measurement	172	$1,198	$206,038	25	$14,619
4	Gate Coefficient	172	$1,323	$227,470	25	$16,140
5	Weir Box	211	$2,230	$470,492	40	$27,419
6	Water information System (WIS)	1	$132,911	$132,911	50	$7,280
7	Totalizing Flow Meter	38	$3,969	$150,820	15	$14,530
			Totals	**$1,501,146**		**$103,320**

Improvements 1 through 5 are required on a farm turnout level. Improvement 6 is required on the system wide level to facilitate data storage and management. Improvement 7 is required to measure pump deliveries (from either supply canals or drains) within the District.

Summaries of the specific improvements required for each gravity farm turnout classification (i.e. low head, medium head and high head), and the associated initial capital costs, are provided in Sections 5.1.1 through 5.1.3 below.

5.1.1 Low Head Device (Propeller Meters)

Table 9 presents the estimated capital costs to measure at 26 low head farm turnouts with propeller meters. The normalized per farm turnout improvement cost is $8,259.

Table 9. Low Head Farm Turnout (Propeller Meter) Cost Estimate

#	Improvements	# of Sites Required	Unit Cost	Sub-Total
1	Orifice Gate	10	$5,017	$50,175
2	Weir Box	21	$2,230	$46,826
3	Propeller Meter	26	$4,528	$117,733
			Total	**$214,734**
			Number of Farm Turnouts Utilizing Propeller Meters	**26**
			Normalized Per Farm Turnout Initial Capital Cost	**$8,259**

Table 9 lists the infrastructure required at each low head gravity farm turnout to use propeller meters (improvements 1 through 3) and the number of gravity farm turnouts that do not currently have the required infrastructure (i.e. the number of sites requiring the specific improvement). The following summarizes the three improvements in Table 9:

1. **Orifice Gate** - for flow control. Includes gate procurement and installation. 10 low head gravity farm turnouts do not currently have orifice gates.
2. **Weir Box** - to maintain full pipe flow and prevent field fluctuation from affecting flow. Includes weir box procurement and installation. 21 low head gravity farm turnouts do not currently have weir boxes.
3. **Propeller Meter** - totalizing propeller meter with mounting brackets. Includes propeller meter procurement and all installation processes. 26 low head gravity turnouts do not currently have propeller meters.

5.1.2 Medium Head Device (Orifice Gates)

Table 10 presents the estimated capital costs to measure at 172 medium head gravity farm turnouts with orifice gates. The normalized per farm turnout improvement cost is $4,718.

Table 10. Medium Head Farm Turnout (Orifice Gate) Cost Estimate

#	Improvements	# of Sites Required	Unit Cost	Sub-Total
1	Orifice Gate	22	$5,017	$110,384
2	Differential Head Measurement	172	$1,198	$206,038
3	Gate Coefficient	172	$1,323	$227,470
4	Weir Box	120	$2,230	$267,579
			Total	**$811,471**
			Number of Farm Turnouts Utilizing Propeller Meters	**172**
			Normalized Per Farm Turnout Initial Capital Cost	**$4,718**

Table 10 lists the infrastructure required at each medium head gravity farm turnout to use orifice gates (improvements 1 through 4) and the number of gravity farm turnouts that do not currently have the required infrastructure (i.e. the number of sites requiring the specific improvement). The following summarizes the three improvements in Table 10:

1. **Orifice Gate** - for flow control. Includes gate procurement and installation. 22 medium head gravity farm turnouts do not currently have orifice gates.
2. **Differential Head Measurement** - infrastructure alterations to allow for the head difference to be read upstream of the orifice gate and approximately 1 foot downstream of the orifice gate. 172 medium head gravity farm turnouts do not currently have the ability to measure differential heads.
3. **Gate Coefficient** - five flow measurements performed at various stages of flow and development of a farm turnout specific rating curve. 172 medium head gravity farm turnouts do not currently have custom farm turnout specific ratings.
4. **Weir Box** - to maintain full pipe flow and prevent field fluctuation from affecting flow. Includes weir box procurement and installation. 120 medium head gravity farm turnouts do not currently have weir boxes.

5.1.3 High Head Device (Weir Boxes)

Table 11 presents the estimated capital costs to measure at 123 high head gravity farm turnouts with weir boxes. The normalized per farm turnout improvement cost is $1,555.

Table 11 lists the infrastructure required at each high head farm turnout to use weir boxes (improvements 1 and 2) and the number of sites that do not currently have the required infrastructure

Table 11. High Head Farm Turnout (Weir Box) Cost Estimate

#	Improvements	# of Sites Required	Unit Cost	Sub-Total
1	Orifice Gate	7	$5,017	$35,122
2	Weir Box	70	$2,230	$156,087
			Total	**$191,210**
			Number of Farm Turnouts Utilizing Propeller Meters	**123**
			Normalized Per Farm Turnout Initial Capital Cost	**$1,555**

(i.e. the number of sites requiring the specific improvement). The following summarizes the two improvements in Table 11:

1. **Orifice Gate** - for flow control. Includes gate procurement and installation. 7 high head gravity farm turnouts do not currently have orifice gates.
2. **Weir Box** - to maintain full pipe flow and prevent field fluctuation from affecting flow. Includes weir box procurement and installation. 70 high head gravity farm turnouts do not currently have weir boxes.

5.2 Approach 2 - RemoteTracker System

Table 12 provides a cost summary for Approach 2, listing the necessary improvements, the number of farm turnouts that require the improvement and the expected life of the improvement.

Table 12. Approach 2 Cost Summary

#	Improvements	# of Sites Required	Unit cost	Initial Capital Sub-Total	Expected Life (years)	Annualized Sub-Total
1	Orifice Gate	39	$5,017	$195,681	25	$13,884
2	Weir Box	211	$2,230	$470,492	40	$27,419
3	RemoteTracker Mounting Plate	304	$325	$98,718	40	$5,753
4	RemoteTracker System	3	$33,063	$99,188	5	$22,910
5	Water Information System (WIS)	1	$132,911	$132,911	50	$7,280
6	Totalizing Flow Meter	38	$3,969	$150,820	15	$14,530
			Totals	**$1,147,810**		**$91,777**

Improvements 1 through 3 are required on a farm turnout level. Improvements 4 and 5 are improvements on the operator or system wide level to facilitate use of the RemoteTracker system. Improvement 6 is required to measure pump deliveries within the District.

1. **Orifice Gate** - for flow control. Includes gate procurement and installation. 39 gravity farm turnouts do not currently have orifice gates.
2. **Weir Box** - to maintain full pipe flow and prevent field fluctuation from affecting flow. Includes weir box procurement and installation. 211 gravity farm turnouts do not currently have weir boxes.
3. **RemoteTracker Mounting Plate** - for mounting wireless water velocity sensor onto turnout. Includes plate fabrication and all installation processes. 304 turnouts do not currently have RemoteTracker plates.
4. **RemoteTracker System** - consists of the wireless water velocity sensor and computing device on a per operator basis. Includes all procurement and assembly costs. Three additional RemoteTracker systems are required.
5. **Water Information System** - water information system to collect and process measurement data. Includes customized database for volumetric accounting. Only one database per District is required.
6. **Totalizing Flow Meter** - for measurement of pump diversions from either supply canals or drains. Includes the meter and installation. 38 known pump farm turnouts within the District will require the installation of totalizing flow meters.

5.3 Approach 3 - Propeller Metering Program

Table 13 provides a cost summary for Approach 3, listing the necessary improvements, and the number of farm turnouts that still require the improvement, and the expected life of each improvement.

Table 13. Approach 3 Cost Summary

#	Improvements	# of Sites Required	Unit Cost	Initial Capital Sub-Total	Expected Life (years)	Annualized Sub-Total
1	Orifice Gate	39	$5,017	$195,681	25	$13,884
2	Weir Box	211	$2,230	$470,492	40	$27,419
3	Propeller Meter	321	$4,528	$1,453,551	20	$116,637
4	Water Information System (WIS)	1	$132,911	$132,911	50	$7,280
5	Totalizing Flow Meter	38	$3,969	$150,820	15	$14,530
			Totals	**$2,403,455**		**$179,751**

Improvements 1 through 3 are required on a farm turnout level. Improvement 4 is required on the system wide level to facilitate data storage and management. Improvement 5 is required to measure pump deliveries within the District.

1. **Orifice Gate** - for flow control. Includes gate procurement and installation. 39 gravity farm turnouts do not currently have orifice gates.

2. **Weir Box** - to maintain full pipe flow and prevent field fluctuation from affecting flow. Includes weir box procurement and installation. 211 gravity farm turnouts do not currently have weir boxes.
3. **Propeller Meter** - totalizing propeller meter with mounting brackets. 321 turnouts do not currently have propeller meters.
4. **Water Information System** - water information system to collect and process measurement data. Includes customized database for volumetric accounting. Only one database per District is required.
5. **Totalizing Flow Meter** - for measurement of pump diversions from either supply canals or drains. Includes the meter and installation. 38 known pump deliveries within the District will require the installation of a totalizing flow meter.

5.4 Maintenance Cost Estimates

Table 14 provides additional details pertaining to the development of annual maintenance costs. Annual maintenance costs are estimated as a percentage of the initial capital costs. Each approach contains a column for the counts of each maintenance item and the annual maintenance cost. The annual maintenance costs are estimated to be $71,207, $70,999 and $153,075 for Approaches 1 through 3, respectively.

Table 14. Operation and Maintenance Cost Summary

Maintenance Item	Annual Maintenance - Percentage of Capital	Annual Maintenance Unit Cost Estimate	Approach 1 - Maximum Use of Existing Devices		Approach 2 - RemoteTracker System		Approach 3 - Propeller Metering Program	
			Number of O&M Items	Annual Maintenance Cost	Number of O&M Items	Annual Maintenance Cost	Number of O&M Items	Annual Maintenance Cost
Propeller Meter	8%	$289	26	$7,505	0	$0	321	$92,657
Weir Box	2%	$36	321	$11,407	321	$11,407	321	$11,407
Orifice Gate	2%	$80	321	$25,667	321	$25,667	321	$25,667
Differential Head Measurement	2%	$19	172	$3,283	0	$0	0	$0
Totalizing Pump Flow Meter	5%	$158	38	$6,009	38	$6,009	38	$6,009
Water Information System	15%	$17,336	1	$17,336	1	$17,336	1	$17,336
RemoteTracker System	8%	$2,645	0	$0	4	$10,580	0	$0
Totals			**-**	**$71,207**	**-**	**$70,999**	**-**	**$153,075**

6.0 Corrective Action Plan

At a special, scheduled meeting on January 4, 2013, the BWGWD Board considered this report and the customer delivery measurement options presented herein. By unanimous vote, the Board accepted the report and adopted measurement Approach 2 - RemoteTracker System as the District's preferred approach for implementing a customer delivery measurement program. The program is intended to comply with the measurement accuracy standards specified in CCR 23 §597 and to be capable of supporting implementation of a water rate structure based at least in part on the volume of water delivered. Such a rate structure remains to be designed and adopted by the Board in the future.

Approach 2 has an estimated capital cost of $1,147,810 assuming that the Gray Lodge water conveyance project is implemented, or a cost of $1,360,202, if the Gray Lodge project does not proceed. Recognizing that these capital improvement costs are relatively large in comparison to the District's current revenue and operating budgets, the Board also unanimously agreed that the program will be implemented on a "pay-as-you-go" basis as discretionary revenues above operating and maintenance costs become available.

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Appendix A. RemoteTracker System Overview and Volumetric Accuracy Certification

A-1.0 Introduction and Summary

This document (1) provides an overview of the RemoteTracker system (Section A-2.0), (2) presents results of initial laboratory and field testing (Section A-3.0) and (3) develops a volumetric accuracy analysis to support compliance of RemoteTracker system with California Code of Regulations Title 23 Division 2 Chapter 5.1 Article 2 Section 597 (CCR 23 §597) (Section A-4.0). Based on the analysis in Section A.3, the expected accuracy in volumetric measurements performed with the RemoteTracker system is ±4.6 percent. Because the RemoteTracker system utilizes a laboratory certified acoustic doppler velocimeter manufactured by SonTek to measure water velocity, the ±5 percent by volume laboratory certification option presented in CCR 23 §597.3(a)(2)(B) applies. Thus, the demonstrated accuracy of the RemoteTracker complies with the ±5 percent by laboratory certification standard. Documentation of the protocols associated with the measurement of the cross-section flow area and duration of delivery, as required by §597.4(e)(3)(B), is presented in Section A-4.0.

A-2.0 RemoteTracker System Overview

The RemoteTracker is an integrated turnout flow measurement, data management and volumetric accounting system developed by H2oTech[15] specifically for agricultural water suppliers in response to CCR 23 §597. The RemoteTracker system is comprised of (1) a wirelessly controlled water velocity sensor, (2) a ruggedized tablet PC in the operator's vehicle and (3) a database running on a file server connected to the internet. The user interface on the tablet PC enables operators to view real time flow data from the wirelessly controlled water velocity sensor via a Bluetooth radio connection while adjusting flows at the turnout gate. Data is automatically transferred over a wireless wide area network (WWAN) to a centralized file server at the District headquarters where it is automatically loaded into a custom database application. The database performs quality control and quality assurance procedures on the data and then develops daily volumes for each customer delivery point (turnout or delivery) within the District.

The wireless water velocity sensor (WWVS) is held in place at a precise location at the pipe outlet by an aluminum or stainless steel mounting bracket. The user interface, shown in Figure A-1, was designed with simplicity and ease of use in mind. If 'Auto Locate' is selected, the program automatically populates the three site identification pull-downs at the top of the screen. If the operator needs to select a different site, the pull-downs can be manually changed. The site selection hierarchy is a three digit abbreviation of 'Operator Route' (i.e. ride, beat or division) on the left, a three digit abbreviation of 'Canal' in the middle and site name on the right. The most recently measured flow, and any pending orders are shown on the 'Home' tab. Many useful reports, including (1) Delivery History, (2) Pending Orders, (3) Fulfilled Orders and (4) Canal Management are available on the 'Reports' tab. These reports can be sorted at any spatial or temporal scale. The data sharing and management framework allows

[15] H2oTech is a company based in Chico, California that focuses on the development of innovative technologies to solve water management challenges.

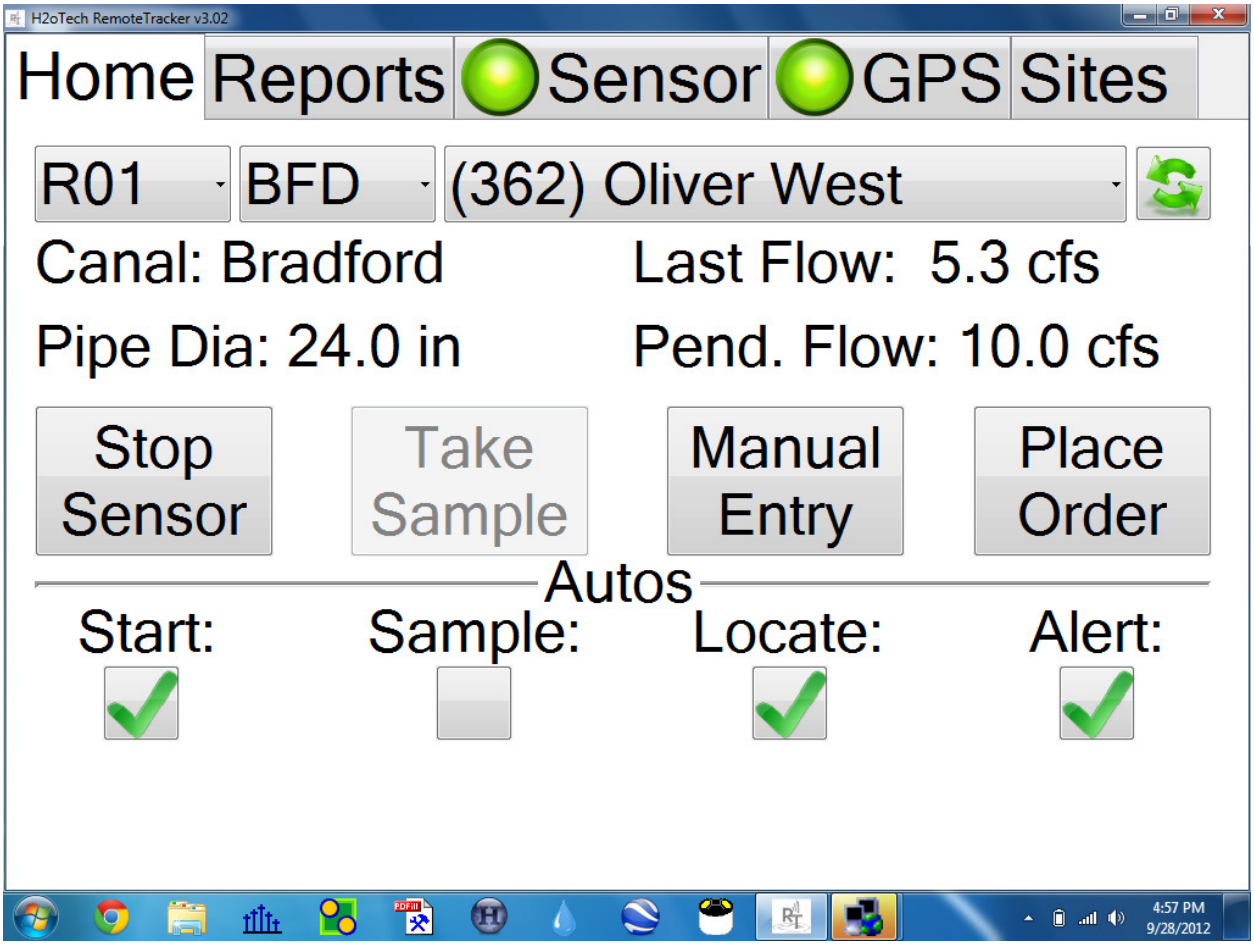

Figure A-1. RemoteTracker User Interface - Home Tab Shown

water order and delivery data collected by any operator to be automatically available for viewing by other operators or management staff in a matter of minutes.

The basic components of the RemoteTracker system are illustrated in Figure A-2. Water velocity is collected by a portable acoustic Doppler velocimeter deployed during measurement by hanging it on brackets permanently installed at each turnout. The brackets are precisely positioned such that the sample volume is at the center of the pipe. Data is transmitted via a class 1 Bluetooth radio to a ruggedized tablet PC where it is processed, displayed and stored. Data is then transferred via a WWAN to a file server at the District headquarters. Data from each operator is aggregated with an automated database procedure and then returned to each operator via WWAN, thereby ensuring that delivery and order data is shared and accessible throughout the entire District.

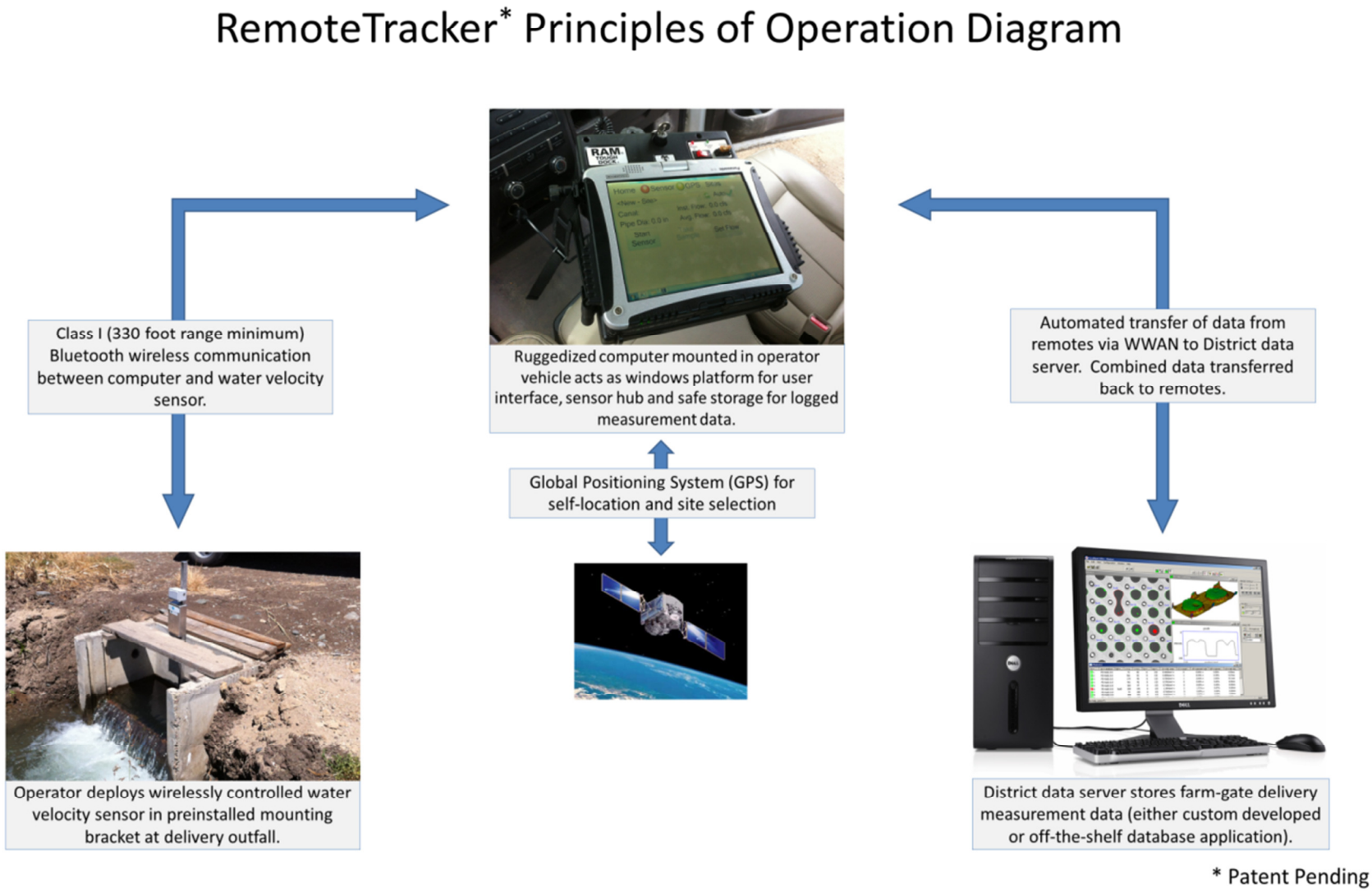

Figure A-2. RemoteTracker Principles of Operation Overview

The key to pipe flow measurement using the RemoteTracker is the consistent relationship between a single velocity measurement at the center of the pipe and the average pipe flow velocity shown in Figure A-3 derived from 146 measurements of center and mean pipe velocity. Based on this relationship, with the pipe diameter and cross sectional area known, the single point velocity can be accurately and reliably correlated with mean pipe velocity (flow rate).

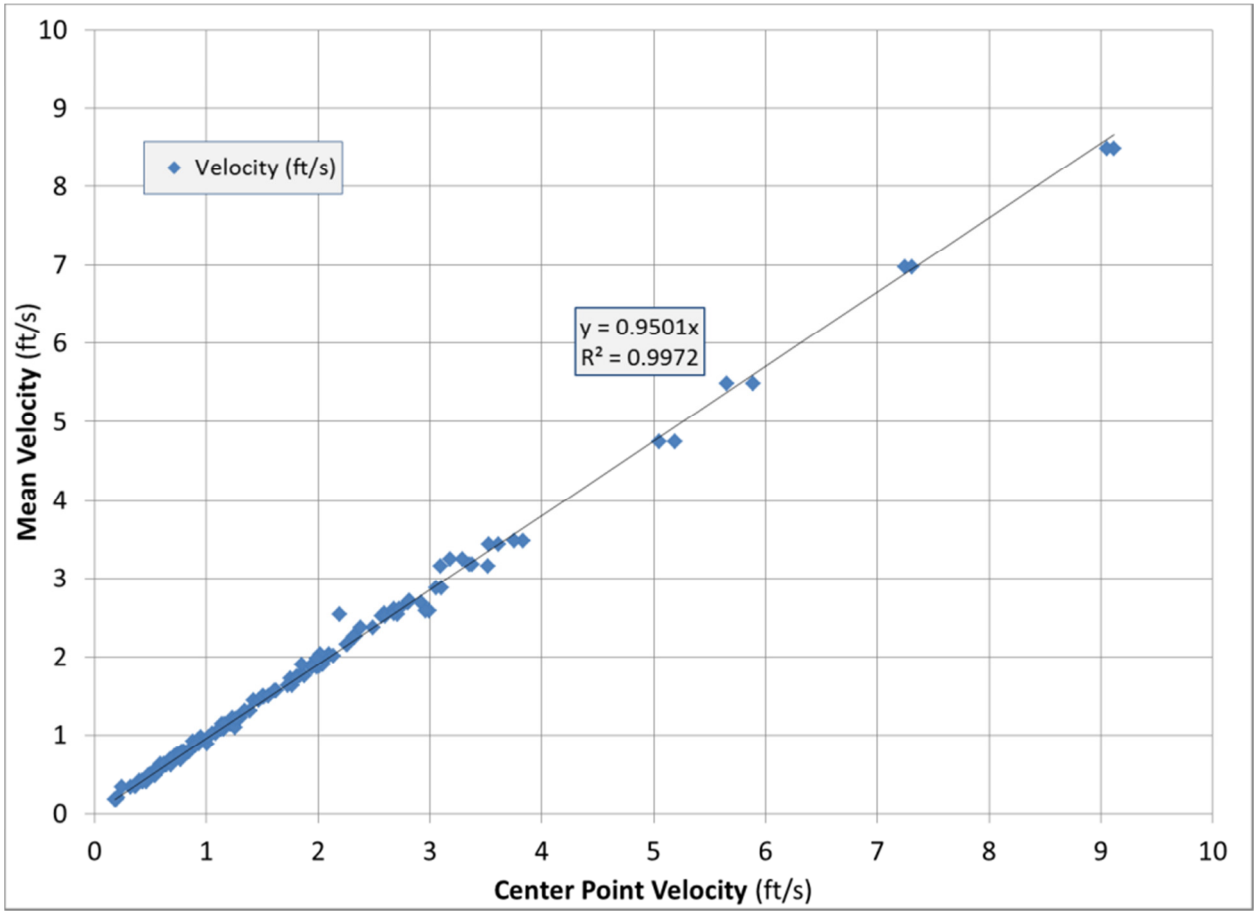

Figure A-3. Relationship between Average and Center Point Pipe Flow Velocity

As with weir and orifice gate measurement, full pipe flow is required for the RemoteTracker to measure correctly. Therefore, a weir box is needed at each turnout to ensure full pipe flow as well as to accommodate the mounting bracket to hold the wireless water velocity sensor so that the sample volume is at the center of the pipe.

The RemoteTracker system can also be integrated with existing or new data management systems at the District office for report generation, accounting and billing. This capability can be added later to provide additional efficiencies in water billing and accounting procedures.

A-3.0 Initial Testing Results

A-3.1 Laboratory Testing

Additional testing was performed at the California State University Chico Agricultural Teaching and Research Center (CSUC ATRC) in July of 2012. Flow data obtained from the RemoteTracker was compared to measurements taken with a 10-inch diameter magnetic flow meter manufactured by Water Specialties. Figure A-4 shows the Water Specialties Magnetic meter with an Endress & Hauser Transit-Time Meter installed just upstream as an additional check. The 3 foot wide by 3 foot deep concrete flume was modified to simulate a typical delivery configuration by forcing all the flow through a 20 foot length of 18 inch HDPE smooth interior wall pipe submerged in the concrete flume. The RemoteTracker wireless water velocity sensor was installed at the pipe outfall using a temporarily constructed headwall with a mounting bracket as shown in Figure A-5.

Figure A-4. Water Specialties Magnetic Flow Meter at CSUC ATRC

Figure A-5. RemoteTracker Wireless Water Velocity Sensor Installed at CSUC ATRC

Seven comparison measurements were made between the RemoteTracker and magnetic meter ranging from 0.5 cfs to just over 3.0 cfs (the maximum pump capacity). The percent difference between the two measurements averaged roughly -2.6 percent with a range of -10.2 to 2.8 percent indicating that the RemoteTracker measurement methodology compares very well with the magnetic meter. Note that the -10.2 percent difference occurred at the lowest flow rate of approximately 0.5 cfs and represents an absolute flow rate difference of just 0.05 cfs between the two measurement methods. The results of the comparison measurements are presented in Figure A-6 where the blue bars represent flow rates obtained with a magnetic meter, the red bars represent flow rates obtained with the RemoteTracker and the green triangles represent the percent difference between the two (secondary vertical axis).

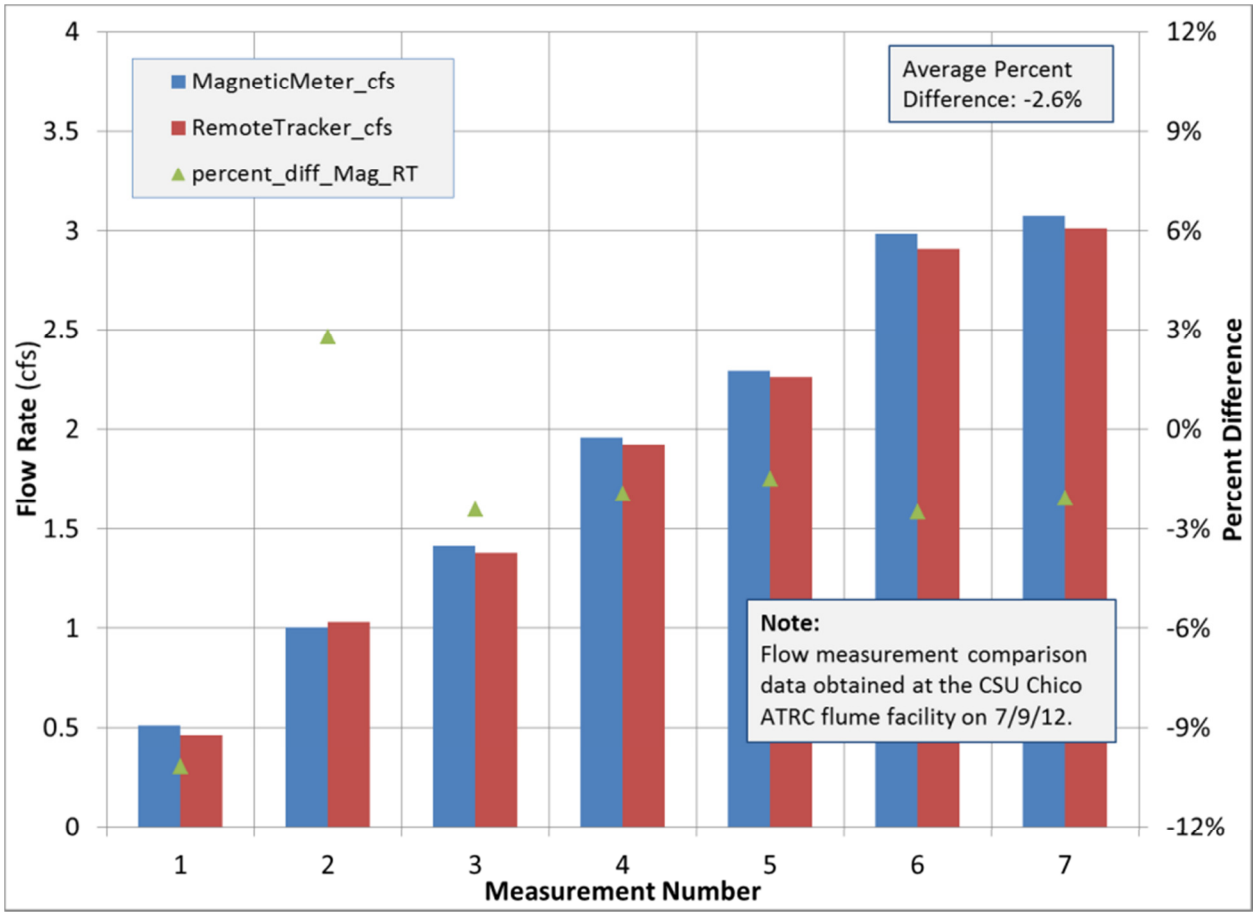

Figure A-6. RemoteTracker and CSUC ATRC Magmeter Comparisons

A-3.2 Field Testing

Five comparison measurements between the RemoteTracker and USGS mid-section method measurements with a SonTek ADV were performed at two turnouts in two irrigation districts (one turnout in each District) in Northern California during the 2011 irrigation season. The turnouts were selected because the delivery spilled into a field ditch (or head ditch) rather than a field, so both a RemoteTracker and a USGS mid-section method measurement (Rantz 1982) could be taken and compared. Figure A-7 shows the cross section report for one of the measurements in a typical earthen head ditch, in this case with a maximum depth of 2.5 feet, top width of 14 feet and bottom width of 5 feet. Typically, velocity measurements were performed at 0.5 foot intervals with velocities averaged over a 40 second period.

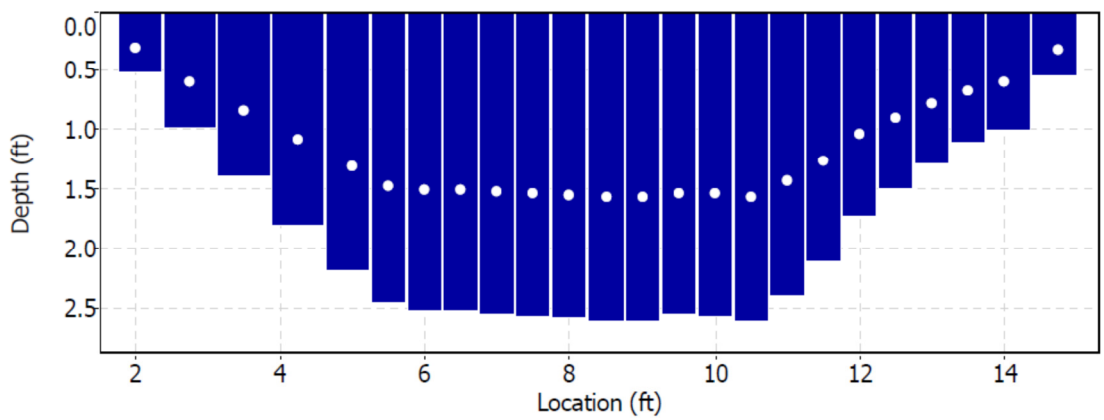

Figure A-7. SonTek ADV Cross Section for Canal Verification Measurement

The percent difference between the RemoteTracker and the USGS mid-section method averaged roughly 0.9 percent with a range of -0.8 to 3.4 percent, indicating that the RemoteTracker measurement methodology compares very well with the standard mid-section open channel methodology. The results of the comparison measurements are presented below in Figure A-8 where the blue bars represent flow rates obtained with a SonTek ADV in an open channel downstream of the turnout, the red bars represent flow rates obtained with the RemoteTracker and the green triangles represent the percent difference between the two (secondary vertical axis).

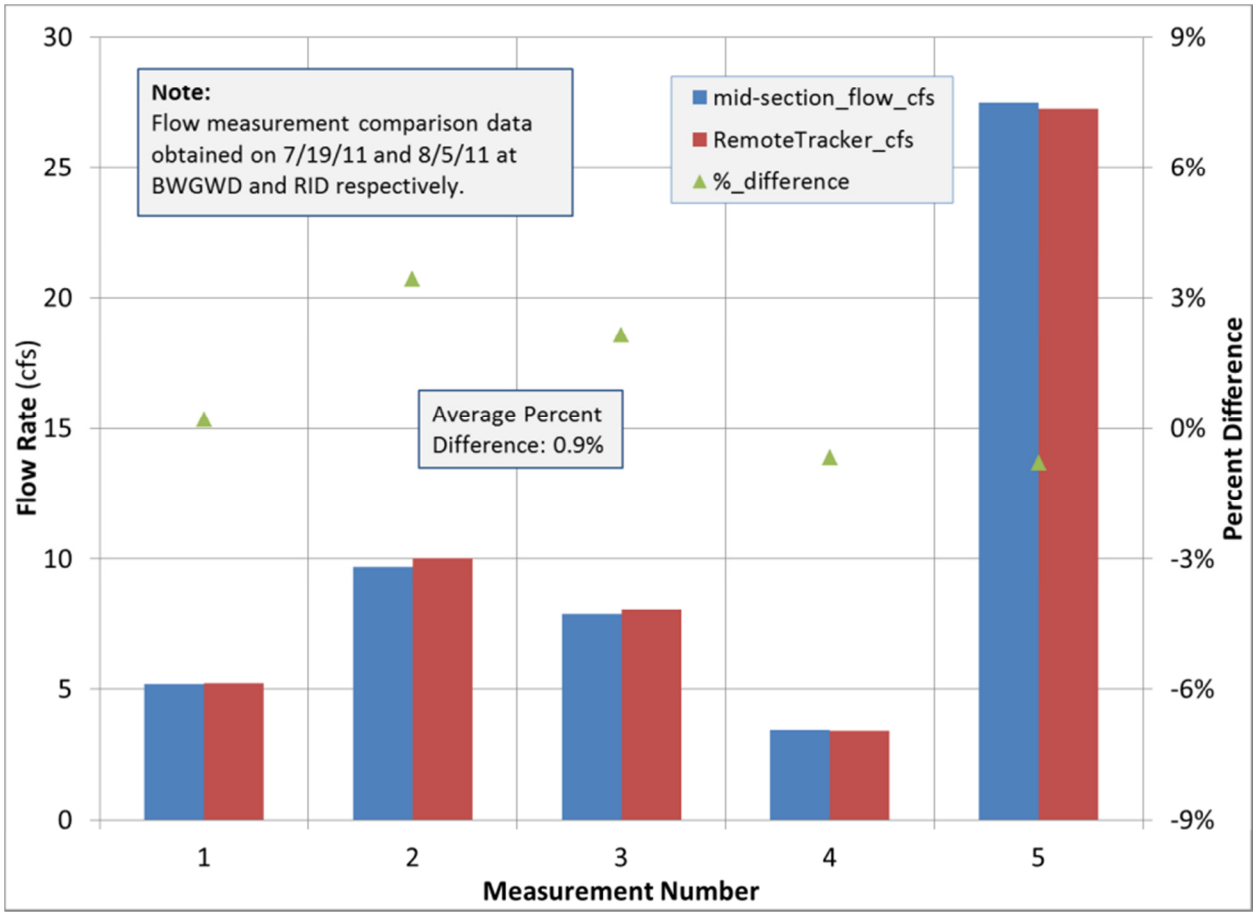

Figure A-8. RemoteTracker and Mid-Section method Comparisons

A-4.0 Volumetric Conversion (CCR 23 §597.4(e)(3))

Accuracy mandates established by CCR 23 §597 apply to delivery volume and not instantaneous flow rate or velocity. CCR 23 §597.4(e)(3)(B) states, "For devices that measure velocity only, the documentation shall describe protocols associated with the measurement of the cross-sectional area of flow and duration of water delivery…". This document provides descriptions of the protocols associated with the measurement of (1) average velocity, (2) cross-sectional area of flow and (3) duration of delivery, in addition to the corresponding accuracies associated with each measurement.

Because the RemoteTracker WWVS measures water velocity only, Equation A-1 suggested in CCR 23 597.4(e)(3)(B) is used to calculate volume.

$$\forall = V * A * \Delta t \qquad \textbf{(Equation A-1)}$$

Where the variables are defined as:

- $\forall$: Volume
- V: Average Velocity
- A: Cross-Section Flow Area
- Δt: Duration of Delivery

This relative accuracy analysis assumes:

- 3 cubic foot per second (cfs) maintenance delivery
- A 24 inch inner diameter delivery pipe
- Normal distribution of measurement errors

A 3 cfs delivery was selected because it represents the lower range of agricultural water delivery rates and accuracy is harder to achieve at low flows. A 24 inch pipe is the average turnout pipe size within most agricultural districts. These assumptions lead to the listed variables having the values presented below.

- V_{RT} = RemoteTracker Velocity Measurement = 1.00 ft/s
- V_{Avg} $*$ = Average Velocity of the pipe at the time of the RemoteTracker spot measurement = 0.95 ft/s (determined by correlation with measured velocity; see Figure A-3)
- D = Pipe Diameter = 2.00 ft
- A = Cross-Section Flow Area = 3.14 ft^2

Based on the following analysis, the expected accuracy in volumetric measurements performed with the RemoteTracker system is ±4.6 percent.

A-4.1 Volumetric Accuracy Analysis Overview

Volumetric accuracy of water deliveries consists of the accuracies in each of the following three components:

- Average Velocity (V_{Avg})
- Cross-Section Flow Area (A)
- Duration of Delivery (Δt)

The total absolute accuracy is found using the following equation;

$$\sigma_{\forall} = \pm\sqrt{\left(\frac{\partial\forall}{\partial V_{Avg}}\sigma_{V_{Avg}}\right)^2 + \left(\frac{\partial\forall}{\partial A}\sigma_A\right)^2 + \left(\frac{\partial\forall}{\partial\Delta t}\sigma_{\Delta t}\right)^2} \qquad \textbf{(Equation A-2)}$$

Where the variables are defined as:

- $\forall$: Volume
- V_{Avg}: Average Velocity
- Δt: Duration of Delivery
- σ: Absolute Accuracy (expressed in the units of the term in question)
- U: Relative Accuracy (expressed as a percentage)

The total relative accuracy is:

$$U_{\forall} = \frac{\sigma_{\forall}}{\forall} = \pm\frac{1}{\forall}\sqrt{\left(\frac{\partial\forall}{\partial V_{Avg}}\sigma_{V_{Avg}}\right)^2 + \left(\frac{\partial\forall}{\partial A}\sigma_A\right)^2 + \left(\frac{\partial\forall}{\partial\Delta t}\sigma_{\Delta t}\right)^2} \qquad \textbf{(Equation A-3)}$$

$$U_{\forall} = \pm\sqrt{\frac{1}{\forall^2}\left(\left(\frac{\partial\forall}{\partial V_{Avg}}\sigma_{V_{Avg}}\right)^2 + \left(\frac{\partial\forall}{\partial A}\sigma_A\right)^2 + \left(\frac{\partial\forall}{\partial\Delta t}\sigma_{\Delta t}\right)^2\right)}$$

Where the partial derivatives are:

$$\frac{\partial\forall}{\partial V_{Avg}} = A\Delta t\ ,\ \frac{\partial\forall}{\partial A} = V_{Avg}\Delta t\ ,\ \frac{\partial\forall}{\Delta t} = V_{Avg}A$$

Substituting in the solutions to the partial derivatives:

$$U_{\forall} = \pm\sqrt{\frac{1}{\forall^2}\left(\left(A\Delta t\sigma_{V_{Avg}}\right)^2 + \left(V_{Avg}\Delta t\sigma_A\right)^2 + \left(V_{Avg}A\sigma_{\Delta t}\right)^2\right)}$$

$$U_{\forall} = \pm\sqrt{\left(\frac{A\Delta t\sigma_{V_{Avg}}}{\forall}\right)^2 + \left(\frac{V_{Avg}\Delta t\sigma_A}{\forall}\right)^2 + \left(\frac{V_{Avg}A\sigma_{\Delta t}}{\forall}\right)^2}$$

$$U_{\forall} = \pm\sqrt{\left(\frac{\sigma_{V_{Avg}}}{V_{Avg}}\right)^2 + \left(\frac{\sigma_A}{A}\right)^2 + \left(\frac{\sigma_{\Delta t}}{\Delta t}\right)^2}$$

This becomes:

$$U_{\forall} = \pm\sqrt{\left(U_{V_{Avg}}\right)^2 + (U_A)^2 + (U_{\Delta t})^2} \qquad \textbf{(Equation A-4)}$$

Based on Equation A-4, the relative accuracies of Average Velocity, Cross-Section Flow Area, and Duration of Delivery are required. The following sections detail their determination.

A-4.2 Relative Accuracy in Velocity

The following bullet points provide protocols for the collection of water velocity data.

- The RemoteTracker WWVS will be deployed in the delivery pipe outfall so that the sample volume is located in the center of the delivery pipe
- Water velocities will be collected with the RemoteTracker WWVS at:
  - The start of all delivery events
  - After any changes in delivery events
- Shutoffs will be recorded on the RemoteTracker user interface with the "Record Shutoff" button at the time the gate is closed

The accuracies in average velocity consist of three parts:

1. $\sigma_{V_{RT}}$: Accuracy of RemoteTracker velocity measurements
2. $\sigma_{V_{Avg}*}$: Accuracy due to the process of correlating RemoteTracker velocity measured at the pipe center and the average velocity of the pipe at the time of the RemoteTracker spot measurement[16]
3. $\sigma_{\Delta V_T}$: Accuracy due to the difference between the average velocity at the time of the RemoteTracker spot measurement and the actual average velocity for the duration of the delivery (i.e. change in velocity over time)

The average velocity relative accuracy is:

[16] Average velocity at the time of the RemoteTracker spot measurement represents a snapshot of the average water velocity in a delivery pipe at the time of the RemoteTracker measurement.

$$U_{V_{Avg}} = \pm \frac{\sigma_{V_{Avg}}}{V_{Avg}}$$ **(Equation A-5)**

Where the variables are defined as:

- V_{Avg}: Average Velocity
- $U_{V_{Avg}}$: Relative Velocity Accuracy
- $\sigma_{V_{Avg}}$: Absolute Velocity Accuracy

The average velocity of the entire irrigation event is the summation of the average velocity at the time of observation and the average change in velocity throughout the remainder of the event due to water level fluctuations.

$$V_{Avg} = V_{Avg} * + \Delta V_T$$ **(Equation A-6)**

Where the variables are defined as:

- V_{Avg}: Average Velocity
- V_{Avg} $*$: Average Velocity at the time of the RemoteTracker spot measurement
- ΔV_T: Average Change in Velocity over time

Therefore:

$$\sigma_{V_{Avg}} = \pm \sqrt{\left(\frac{\partial V_{Avg}}{\partial V_{AvgO}} \sigma_{V_{AvgO}}\right)^2 + \left(\frac{\partial V_{Avg}}{\partial \Delta V_T} \sigma_{\Delta V_T}\right)^2}$$ **(Equation A-7)**

Where the partial derivatives are:

$$\frac{\partial V_{Avg}}{\partial V_{Avg*}} = 1, \ \frac{\partial V_{Avg}}{\partial \Delta V_T} = 1$$

Substituting in the solutions to the partial derivatives:

$$\sigma_{V_{Avg}} = \pm \sqrt{\left(\sigma_{V_{Avg*}}\right)^2 + \left(\sigma_{\Delta V_T}\right)^2}$$ **(Equation A-8)**

The following subsections present (1) the accuracy of the RemoteTracker velocity measurements, (2) the accuracy of the average velocity at the time of the RemoteTracker spot measurements ($\sigma_{V_{Avg}*}$) and (3) the accuracy in the change in average velocity over time ($\sigma_{\Delta V_T}$).

A-4.2.1 Accuracy of RemoteTracker Velocity Measurement

The RemoteTracker system uses a SonTek ADV for water velocity measurements. The SonTek ADV technical specifications sheet lists a velocity measurement error of 0.01 or 1.0 percent (SonTek 2006). Therefore, $\sigma_{V_{RT}}$ is equal to 0.010 ft/s, or 1.0 percent of 1.00 ft/s (V_D).

A-4.2.2 Accuracy of the Average Velocity at the Time of the RemoteTracker Spot Measurement

The average velocity is computed as the product of the velocity measured by the RemoteTracker and the coefficient correlating the RemoteTracker velocity measurement to the average velocity at the time of the RemoteTracker spot measurement.

$$V_{Avg}* = CV_{RT} \qquad \textbf{(Equation A-9)}$$

Where the variables are defined as:

- $V_{Avg}*$: Average velocity at the time of the RemoteTracker spot measurement
- C: Coefficient correlating the RemoteTracker velocity measurement to the average velocity at the time of the RemoteTracker spot measurement, which is equal to 0.95 (see Figure A-3)
- V_{RT}: RemoteTracker velocity measurement

Therefore:

$$\sigma_{V_{Avg}*} = \pm\sqrt{\left(\frac{\partial V_{Avg}*}{\partial C}\sigma_C\right)^2 + \left(\frac{\partial V_{Avg}*}{\partial V_{RT}}\sigma_{V_{RT}}\right)^2} \qquad \textbf{(Equation A-10)}$$

Where the partial derivatives are:

$$\frac{\partial V_{Avg}*}{\partial C} = V_{RT}, \frac{\partial V_{Avg}*}{\partial V_{RT}} = C$$

Substituting in the solutions to the partial derivatives:

$$\sigma_{V_{Avg}*} = \pm\sqrt{(V_{RT}\sigma_C)^2 + \left(C\sigma_{V_{RT}}\right)^2} \qquad \textbf{(Equation A-11)}$$

Based on water velocity data collected, the average error introduced by converting the RemoteTracker velocity measurement to the average velocity at the time of the RemoteTracker spot measurement (σ_C) is 0.014 or 1.4 percent.

Inserting the determined values into Equation A-11:

$$\sigma_{V_{Avg^*}} = \pm\sqrt{(1.0 * 0.014)^2 + (0.95 * 0.010)^2} = \pm\, 0.017\ ft/s$$

A-4.2.3 Accuracy of the Change in Velocity over Time

A Microsoft Access database was developed to assess the accuracy in the change in velocity over time. Based on the orifice equation, the change in velocity through an orifice is solely a function of changes in head (or difference between upstream and downstream water level). Only water level data from the typical irrigation season (i.e. May through August) was used. It was assumed that measurements of velocity were performed every three days.

The difference between the head observed every three days and the actual average of the 15 minute data during the three day period was computed for each 15 minute record and then averaged over the observation period. Equation A-14 was then used to calculate the change in velocity over time (ΔV_T) for each three day period. The initial head (h_i) was assumed to be 0.5 feet to simulate a low head delivery. A low head was chosen because water level fluctuations impact the velocity of low head deliveries more significantly than high head deliveries.

Rearranging Equation A-6:

$$\Delta V_T = V_{Avg} - V_{Avg}\ *$$

From the orifice equation:

$$V = C(2gh)^{0.5} \qquad \textbf{(Equation A-12)}$$

Where the variables are defined as:

- V: Velocity
- C: Discharge Coefficient
- g: gravitational constant
- h: Head

Orifice gates in most agricultural water districts operate under submerged conditions (i.e. not free flow conditions). As upstream canal water levels fluctuate, the flow through the orifice would theoretically vary as a function of the changes in canal water level to the one-half power. However, since the orifice gates are submerged, the hydraulically connected downstream water level also varies together with the upstream canal water level. This provides a damping effect on the overall change in velocity due to upstream water level fluctuations. The California Polytechnic State University at San Luis Obispo Irrigation Training and Research Center (ITRC) suggest using a power of 0.38 in the orifice equation to

simulate the damping effect of submergence for a range of downstream channel conditions (Burt and Geer 2012).

$$V = C(2gh)^{0.38}$$ **(Equation A-13)**

Substituting values:

$$\Delta V_T = C(2gh_{avg})^{0.38} - C(2gh_O)^{0.38}$$

Where the variables are defined as:

- h_{avg}: Average Head
- h_O: Observed Head

Factoring:

$$\Delta V_T = C(2g)^{0.38}\left((h_{avg})^{0.38} - (h_O)^{0.38}\right)$$

Substituting values:

$$\Delta V_T = C(2g)^{0.38}\left((h_i + \Delta h_{avg})^{0.38} - (h_i)^{0.38}\right)$$ **(Equation A-14)**

Where the variables are defined as:

- h_i= Initial head at time of observation
- Δh_{avg}= average change in head

Since the volumetric reporting mandates apply to a monthly or bi-monthly basis (California Water Code §531.10(a)), the change in velocity over time was then averaged on a monthly time step. The average of the absolute values of each of the average monthly changes in velocity over time was taken across all nine sites. Largely due to the fact that water level fluctuations are normally distributed, the results of the hydraulic database model suggest that the average change in velocity over time due to water level fluctuation is:

$$\sigma_{\Delta V_T} = \pm\, 0.033\, ft/s$$

Based on the evaluation of continuous upstream and downstream water level data from 14 irrigation events in RD 108 with an average duration of five days, the average change in velocity over time was determined to be ±1.0 percent. In the context of this analysis, the accuracy in the change in velocity over time would be:

$$\sigma_{\Delta V_T} = \pm 1.0\% \; or \pm 0.010 \; ft/s$$

Therefore, utilizing the value of ±0.033 ft/s for the volumetric accuracy analysis is a conservative assumption.

Inserting the calculated values into Equation A-8, the average velocity accuracy is:

$$\sigma_{V_{Avg}} = \pm\sqrt{(0.017)^2 + (0.033)^2} = 0.037 \; ft/s$$

The relative accuracy of the average velocity is:

$$\boxed{U_{V_{Avg}} = \pm\frac{\sigma_{V_{Avg}}}{V_{Avg}} = \pm\frac{0.037 \; ft/s}{0.95 \; ft/s} = \pm\, 0.039 \; or \; 3.9\%}$$

A-4.3 Relative Accuracy in Cross-Section Flow Area

The following bullet points provide protocols for the collection of cross-section flow area data.

- The cross-section flow area will be calculated by measuring the inner diameter of the delivery pipe at the location of the water velocity measurement and using Equation A-16 to calculated area from inner diameter
- Inner pipe diameters will be measured with best professional practices when the pipe is dry

The accuracy in the inner pipe diameter measurement is assumed to be 0.02 feet (or 1/4 inch). The relative accuracy due to area is:

$$U_A = \pm\frac{\sigma_A}{A} \qquad \textbf{(Equation A-15)}$$

The correlation between diameter and area is:

$$A = \frac{\pi \mathrm{D}^2}{4} \qquad \textbf{(Equation A-16)}$$

Where the variables are defined as:

- A: Cross-Section Flow Area
- π: Pi
- D: Inner Diameter

The accuracy is:

$$\sigma_A = \pm\sqrt{\left(\frac{\partial A}{\partial D}\sigma_D\right)^2}$$ **(Equation A-17)**

Where the partial derivative is equal to:

$$\frac{\partial A}{\partial D} = \frac{2\pi D}{4} = \frac{\pi D}{2}$$

The assumed pipe is 2.00 feet (24 inch) in diameter, giving an area of 3.142 ft^2

$$\sigma_A = \pm\sqrt{\left(\frac{\partial A}{\partial D}\sigma_D\right)^2} = \sqrt{\left(\frac{\pi D}{2}0.02\right)^2} = \sqrt{\left(\frac{\pi 2}{2}0.02\right)^2} = \pm\, 0.063\, ft$$

The relative accuracy in the cross-section flow area is:

$$\boxed{U_A = \pm\frac{\sigma_A}{A} = \pm\frac{0.063\, ft}{3.142\, ft} = \pm\, 0.020\ or\ 2.0\%}$$

A-4.4 Relative Accuracy in Duration of Delivery

The following bullet points provide protocols for the collection of duration of delivery data.

- The start time for delivery will be the date and time recorded in the RemoteTracker system when a velocity measurement is taken at the start of a delivery
- The stop time for delivery will be the date and time recorded in the RemoteTracker system when either:
    - "Record Shutoff" is pressed after a gate is closed at the end of a delivery or
    - A new velocity measurement is taken after a change in delivery flow rate is made

A conservative value for the duration of an irrigation event is assumed to be a period of 24 hours. The possible accuracy in duration measurement is considered to be 15 minutes for the startup and 15 minutes for the shutoff (or 0.25 hours for both). Realistically, the actual accuracy in duration is much smaller when using the RemoteTracker system since the operator is recording water velocity data on site when gate position changes are made. The relative accuracy due to duration of delivery is:

$$U_{\Delta t} = \pm\frac{\sigma_{\Delta t}}{\Delta t}$$ **(Equation A-18)**

Where:

$$\Delta t = Et - St$$ **(Equation A-19)**

Where the variables are defined as:

- Δt: Duration of Delivery
- St: Start Time
- Et: End Time

The accuracy of the Duration of Delivery is:

$$\sigma_{\Delta t} = \pm\sqrt{\left(\frac{\partial \Delta t}{\partial St}\sigma_{St}\right)^2 + \left(\frac{\partial \Delta t}{\partial Et}\sigma_{Et}\right)^2} \qquad \textbf{(Equation A-20)}$$

Where the partial derivatives are equal to:

$$\frac{\partial \Delta t}{\partial St} = 1,\ \frac{\partial \Delta t}{\partial Et} = 1$$

$$\sigma_{\Delta t} = \pm\sqrt{(\sigma_{St})^2 + (\sigma_{Et})^2} = \sqrt{(.25)^2 + (0.25)^2} = 0.35\ hrs$$

The relative accuracy in the duration of delivery is:

$$\boxed{U_{\Delta t} = \pm\frac{\sigma_{\Delta t}}{\Delta t} = \pm\frac{0.35}{24} = \pm\ 0.015\ or\ 1.5\%}$$

A-4.5 Relative Accuracy in Volume

As previously stated this relative accuracy assumes a 3 cfs maintenance delivery in a 24" pipe. Inserting the calculated accuracy value for each component, the relative accuracy is as follows:

$$U_{\forall} = \pm\sqrt{\left(U_{V_{Avg}}\right)^2 + (U_A)^2 + (U_{\Delta t})^2} \qquad \textbf{(Equation A-21)}$$

Inserting all calculated accuracy values the relative accuracy in volumetric measurements is:

$$U_{\forall} = \pm\sqrt{(.039)^2 + (.020)^2 + (.015)^2}$$

$$\boxed{U_{\forall} = \pm\ 0.046\ or\ \pm\ 4.6\%}$$

Based on the foregoing analysis and the resulting ±4.6% accuracy in delivery volume determined for the RemoteTracker, the RemoteTracker complies with the ±5.0% accuracy mandate in CCR 23 §597 for laboratory testing.

Appendix B. Detailed Cost Estimates

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$400	0%	$400	
							$400	$400
Preparation								
2	Mobilization	ls	1	5%	$200	0%	$200	
							$200	$200
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	18" Orifice Gate	ea	25%	$1,890	$473	15%	$543	
7	24" Orifice Gate	ea	50%	$2,110	$1,055	15%	$1,213	
8	30" Orifice Gate	ea	25%	$2,736	$684	15%	$787	
9	Concrete Headwall	ea	1	$1,265	$1,265	15%	$1,455	
10								
11								
12								
13								
14								
							$3,998	$3,998
PROJECT SUBTOTAL								$4,598
Project Administration								
15	Construction Management and Overhead	ls	1	10%	$420	0%	$420	$420
TOTAL								**$5,017**

Figure B-1. Orifice Gate Unit Cost Breakdown

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$115	0%	$115	
							$115	$115
Preparation								
2	Mobilization	ls	1	5%	$58	0%	$58	
							$58	$58
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	Calibration and Rating - Orifice Gate	ls	1	$1,000	$1,000	15%	$1,150	
7								
8								
9								
10								
11								
12								
13								
14								
							$1,150	$1,150
PROJECT SUBTOTAL								$1,323
Project Administration								
15	Planning/mobilization contingency	ls	1	0%	$0	0%	$0	$0
TOTAL								**$1,323**

Figure B-2. Orifice Gate Calibration Unit Cost Breakdown

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$95	0%	$95	
							$95	$95
Preparation								
2	Mobilization	ls	1	5%	$48	0%	$48	
							$48	$48
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	Stilling Well 1' Downstream of Gate	ea	1	$530	$530	15%	$610	
7	Staff Gages	ea	1	$300	$300	15%	$345	
8								
9								
10								
11								
12								
13								
14								
							$955	$955
PROJECT SUBTOTAL								$1,098
Project Administration								
15	Construction Management and Overhead	ls	1	10%	$100	0%	$100	$100
TOTAL								**$1,198**

Figure B-3. Orifice Gate Differential Head Unit Cost Breakdown

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$178	0%	$178	
							$178	$178
Preparation								
2	Mobilization	ls	1	5%	$89	0%	$89	
							$89	$89
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	4-ft concrete weir box	ea	1	$1,265	$1,265	15%	$1,455	
7	Aggregate Base	cy	3	$60	$180	15%	$207	
8	Weir boards and stand plate	ea	1	$100	$100	15%	$115	
9								
10								
11								
12								
13								
14								
							$1,777	$1,777
PROJECT SUBTOTAL								$2,043
Project Administration								
15	Construction Management and Overhead	ls	1	10%	$187	0%	$187	$187
TOTAL								**$2,230**

Figure B-4. Weir Box Cost Breakdown

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$316	0%	$316	
							$316	$316
Preparation								
2	Mobilization	ls	1	5%	$158	0%	$158	
							$158	$158
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	Mag Meter	ea	1	$2,750	$2,750	15%	$3,163	
7								
8								
9								
10								
11								
12								
13								
14								
							$3,163	$3,163
PROJECT SUBTOTAL								$3,637
Project Administration								
15	Construction Management and Overhead	ls	1	10%	$332	0%	$332	$332
TOTAL								**$3,969**

Figure B-5. Totalizing Flow Meter Unit Cost Breakdown

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$11,558	0%	$11,558	
							$11,558	$11,558
Preparation								
2	Mobilization	ls	1	5%	$5,779	0%	$5,779	
							$5,779	$5,779
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	MS Office Suite	ea	1	$500	$500	15%	$575	
7	Database Customization for Volumetric Tracking	ls	1	$30,000	$30,000	15%	$34,500	
8	Development of Automated Quality Control Proce	ls	1	$25,000	$25,000	15%	$28,750	
9	Creating Invoicing and Accounting Process	ls	1	$45,000	$45,000	15%	$51,750	
10								
11								
12								
13								
14								
							$115,575	$115,575
PROJECT SUBTOTAL								$132,911
Project Administration								
15	Planning/mobilization contingency	ls	1	0%	$0	0%	$0	$0
TOTAL								**$132,911**

Figure B-6. Water Information System Unit Cost Breakdown

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$2,875	0%	$2,875	
							$2,875	$2,875
Preparation								
2	Mobilization	ls	1	5%	$1,438	0%	$1,438	
							$1,438	$1,438
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	RemoteTracker System	ea	1	$25,000	$25,000	15%	$28,750	
7								
8								
9								
10								
11								
12								
13								
14								
							$28,750	$28,750
PROJECT SUBTOTAL								$33,063
Project Administration								
15	Planning/mobilization contingency	ls	1	0%	$0	0%	$0	$0
TOTAL								**$33,063**

Figure B-7. RemoteTracker System Unit Cost Breakdown

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$26	0%	$26	
							$26	$26
Preparation								
2	Mobilization	ls	1	5%	$13	0%	$13	
							$13	$13
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	RemoteTracker Plate	ea	1	$200	$200	15%	$230	
7	Pipe Diameter measurements	ea	1	$25	$25	15%	$29	
8								
9								
10								
11								
12								
13								
14								
							$259	$259
PROJECT SUBTOTAL								$298
Project Administration								
15	Construction Management and Overhead	ls	1	10%	$27	0%	$27	$27
TOTAL								**$325**

Figure B-8. RemoteTracker Plate Unit Cost Breakdown

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$361	0%	$361	
							$361	$361
Preparation								
2	Mobilization	ls	1	5%	$180	0%	$180	
							$180	$180
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	18" Propeller Meter	ea	25.0%	$2,920	$730	15%	$840	
7	24" Propeller Meter	ea	50.0%	$3,210	$1,605	15%	$1,846	
8	30" Propeller Meter	ea	25.0%	$3,210	$803	15%	$923	
9	Propeller Meter Plate	ea	1	$0	$0	15%	$0	
10								
11								
12								
13								
14								
							$3,608	$3,608
PROJECT SUBTOTAL								$4,149
Project Administration								
15	Construction Management and Overhead	ls	1	10%	$379	0%	$379	$379
TOTAL								**$4,528**

Figure B-9. Propeller Meter Unit Cost Breakdown

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3.10.4 Potential Projects to Enhance Water Management Capabilities

A description of potential projects to enhance BWGWD water management capabilities is provided on the following pages.

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Attachment 3.10.4: Potential Projects to Enhance BWGWD Water Management Capabilities

Overview

A total of three improvement projects to enhance water management by Biggs West Gridley Water District (BWGWD) were evaluated. These range from comprehensive system modernization to localized projects related to boundary outflow and spill measurement, and drain water recovery. For each project, reconnaissance level implementation costs have been estimated. It is anticipated that these projects will be implemented over time, subject to the availability of funding and project prioritization. Potential improvements are assembled into the following project categories:

1. System Modernization
2. Boundary Outflow and Primary Spill Measurement
3. Drain Water Recovery

Summary of Cost Estimation Procedure

Reconnaissance level cost estimates were prepared for each improvement project as a basis for prioritization and funding of site improvements. The following summary of the cost estimation procedure applies to all projects described in this attachment.

Site inventories were completed with the help of district staff, and several sites were visited to provide sufficient information for developing generalized conceptual designs for each site type to estimate material and labor quantities; however, sites were not surveyed in detail, and dimensions of structures and cross sections were gathered only at a sample of locations. A general observation from the field visits was that many of the sites in a specific category (e.g. water level control) were similar in design and only varied in capacity. For this reason, conceptual designs were developed for each site type in several configurations and in a range of capacities as appropriate. The typical conceptual designs are listed in Table 1.

Table 1. Typical conceptual designs and the variations/configurations developed for purposes of cost estimation.

	Typical Design	Variations/Configurations
A	Acoustic Doppler velocimeter in lined section of channel	
B	Acoustic Doppler velocimeter in unlined section of channel	I. High capacity canal II. Mid-range capacity canal
C	New Precast Spill Box with 36" propeller meter at d/s end	I. 4 ft weir box II. 6 ft weir box
D	Precast headwall with new 36" undershot gate, piping and propeller meter at d/s end	
E	New Precast Spill Box with fixed, sharp-crest weir plate	I. 4 ft weir box II. 6 ft weir box
F	Precast headwall with new 36" undershot gate, piping and RemoteTracker[1] bracket at d/s end. RemoteTracker not included.	
G	New precast spill box with piping and RemoteTracker bracket at d/s end. RemoteTracker not included.	
H	Locally automated combination weir	450, 250, 150, 75, 50, and 25 cfs capacity
I	Manually Adjusted Undershot Gates	Cost estimated on a per square foot of gate area basis
J	Automated Flow Control Gates	Cost estimated on a per square foot of gate area basis
K	SCADA hardware and related communication components	I. No add'l power source II. No add'l power source, w/ PLC III. W/ solar power system and PLC IV. W/ solar power system, pressure transducer and related components

Costs for these typical designs were developed based on estimates of required site components, quantities, and unit costs.

Unit Costs

Unit costs for the various work items and materials were compiled from a variety of sources including published values, local suppliers, contractors and installers, or references from works previously completed by Davids Engineering or others. Standard unit prices were increased by 10% assuming prevailing labor rates will apply. Costs include material and equipment costs, installation labor, shipping, and tax (where applicable).

Cost types fall into three categories: Direct Costs, Indirect Costs, and Contingencies. Direct costs are associated with physical site improvements, while indirect costs represent other project costs such as engineering and design, environmental permitting, construction management, administration and legal, and overhead, and are included as a percentage of the sum of extended costs plus the contingency.

[1] The RemoteTracker is a portable measurement device developed specifically as a water district delivery measurement solution in response to the passage of State of California Senate Bill x7-7 in 2009. The device is currently being utilized by some Feather River water users.

Contingency is applied to the subtotal of direct costs based on uncertainties present at this level of design and cost estimation and to account for unforeseen requirements.

Total indirect costs plus contingency varied by site type to account for differences in site complexities, construction effort, engineering and design requirements, the source of the unit cost information, and professional judgment. Mark-ups are summarized in Table 2.

Table 2. Summary of range of percentage multipliers applied to cost estimate to account for indirect costs and contingencies.

Range of Percentages Applied to Total Direct Costs			
Engineering & Construction Management	10%	to	20%
Legal, Environmental and Administration	0%	to	20%
Total =	10%	to	40%
Percentage Applied to Total Site Cost			
Contingency	10%	to	20%

All projects were assumed to be designed and constructed using competitive bidding processes. It is likely that several of the site improvements could be implemented under a design-build scenario, or even by district forces, both of which might be less expensive than the costs estimated in this analysis.

Quantities

Canal capacities were either determined through consultation with district operators or estimated using Manning's equation for open channel flow using a combination of measured and assumed cross sectional geometry. For each canal, the top water width was measured at several locations using the point-to-point utility in GoogleEarth. Canal water depths were estimated based on spot field observations and by designating each canal a Main, Lateral, or sublateral canal. Average slopes along the canal lengths were estimated from GoogleEarth and USGS topographic maps. A Manning's "n" of 0.033 was used assuming excavated earthen canals, winding and sluggish with grass and some weeds, as defined in Te Chow (1959)[2]. Where available, calculated capacities were validated with measured capacities or typical peak diversions and globally adjusted as appropriate.

Quantities for larger heading and water level control structures were independently calculated and compared with conceptual structures designed for the Sutter Butte Regional Conveyance Study[3], conceptual structures in the WCWD Draft 20-Year Capital Improvements Plan, and with 60% design cost estimates[4] for the BWGWD Gray Lodge Wildlife Area Supply Project.

Site Specific Improvement costs

For each site identified for improvements, applicable designs and base costs for typical sites were either used without modification, adjusted to reflect actual site conditions, or combined with components for other sites to create site specific improvement capital costs and annualized costs, as appropriate.

[2] Te Chow, Ven. 1959. Open Channel Hydraulics. The Blackburn Press, Caldwell, New Jersey, U.S.A.
[3] GEI Consultants, 2006. Regional Conveyance System Improvement Project – Final Report, May 2006. Completed for Sutter Extension Water District by Bookman-Edmonston, a division of GEI Consultants, Inc.
[4] Engineer's Opinion of Probable Construction Cost, 60% Design. October 2011. Prepared by Provost and Pritchard Consulting Engineers.

Annual costs

Annual capital repayment was estimated for each item using an amortization rate of 5 percent and capital recovery factors calculated using the estimated expected life of each cost item. Total annual costs also include annual operations and maintenance (O&M) costs associated with the improvement. O&M costs were estimates as a percentage of the total extended cost of the item. The percentage ranged from 0 percent for items not requiring annual maintenance to 5 percent for electrical or mechanical components where more frequent O&M is necessary to ensure reliable operation and system longevity.

Project 1: System Modernization Project

Project Description

The system modernization program developed aligns with BWGWD's desire to replace and improve existing infrastructure, to develop data to evaluate existing operations and potential future water management improvements, and to develop and implement management strategies and tools to meet water management objectives, including water conservation at the district scale and improved delivery service to customers.

System modernization is generally implemented to achieve one or more of the following goals:

1. Increase the efficiency of the distribution system to conserve water at the district scale,
2. Increase the efficiency of the distribution system to irrigate additional land,
3. Increase the level of service provided to growers and respond to changes in cropping or irrigation method,
4. Reduce risks to the safety of operations staff, and
5. Improve the overall operability and management of the District.

System modernization planning processes can take a narrow, focused path on a handful of sites that can be completed in a short time frame or (the generally preferred approach) a broadened perspective that evaluates the entire system, including their interrelation and interaction with the objective of optimally meeting the modernization goals of the district. A comprehensive modernization plan provides a road map for a phased implementation process that allows for improvements to occur over time at a pace that considers available funds and implements priority improvements first to meet objectives in the most cost effective manner possible. Additionally, this project will help the District realize additional benefits from the Gray Lodge Wildlife Area Supply Project that is planned to improve much of the District's main canal infrastructure with the objective of supplying the Gray Lodge area with a more reliable supply.

Sites within each phase may be completed all at once, or on a prioritized basis, but generally beginning at the head of the system and proceeding downstream to maximize benefits relative to implementation costs. The system modernization strategy developed for Biggs West Gridley Water District is a top-down strategy involving four phases with flow measurement being an overarching improvement to meet objectives, as well as water management in general. It is anticipated that the phasing of improvements to individual sites may differ from those described herein as informed by evaluation of opportunities, costs, and other considerations over time.

The system modernization program generally includes improvements to three site categories: Heading structures, upstream water level control structures, and spill structures. The objectives for each of these site types is described in Table 3.

Table 3. System Modernization Objectives by Site Category.

Site Category	General Modernization Objective
Heading	• Replace old, aging and/or deteriorated structures and equipment, as needed. • Provide increased accuracy, repeatability, and consistency in downstream deliveries to district customers prevent farm runoff and tail end spills. • Improve ability for flow adjustments to prevent spill and enhance delivery service. • Increase safety of site for operators.
Upstream Water Level Control	• Replace old, aging and/or deteriorated structures and equipment, as needed. • Maintain constant upstream deliveries by reducing fluctuation in desired upstream water level over a range of canal flow rates. • Simplify operations by reducing the need to add or remove flashboards to maintain water levels across a range of flows. • Facilitate the ability to make frequent flow changes through the system, as needed. • Consolidate safety spills by eliminating intermediate safety spills, where practical. • Increase safety site for operators.
Spills	• Provide accurate and accessible measurement of spillage flow rate from the lateral as feedback loop on heading operation, general lateral operation, and District water accounting. • Increase safety of operating site.

The specific improvements completed under each of the four phases of modernization is described in additional detail below.

Phase I System Modernization

The first phase would concentrate on primary inflow and operational outflow locations. These are generally the primary diversion locations or headings and main or primary canal end outflow points. The type and sophistication of improvement required to meet objectives varies by site, but the general objective is to provide improved control over the water that enters the district, as informed by improved information describing the timing and amount of water leaving the district. Readily accessible measurement of inflows and outflows has several benefits, including information for operational adjustments, data for water accounting and billing, and information to support prioritization of improvements by quantifying potential benefits.

For BWGWD, the primary inflow points are the Belding Lateral at Biggs Extension Canal. Currently, BWGWD contacts the Joint Water District (Joint Board) manager for daily changes in inflow to the Belding Lateral. The Joint Board operator makes adjustments into the Biggs Extension Canal and BWGWD operators adjust the Belding Lateral gates accordingly. Flows into the Belding Lateral are measured by BWGWD downstream of the heading using an acoustic Doppler meter. The accuracy of this site has not been verified and, because a flow display is not available at the heading, are less inclined to verify the effects of gate changes. Additionally, fluctuations in the Biggs Extension Canal can cause substantial fluctuations in flow through the gates which can, in turn, lead to downstream surpluses or deficiencies[5]. Accurate flow measurement at primary inflow locations is paramount to achieve modernization objectives because it allows for more accurate and precise management of inflows to the

[5] A modernization plan has been developed for the Joint Board as part of this Regional AWMP that would seek to remedy water level fluctuation issues in the Sutter Butte and Biggs Extension canals.

distribution system. Therefore, recommended improvements at the heading structures include independent stream gaging of the Belding Lateral to calibrate the existing device, and relocation of the meter if needed. The addition of remotely monitoring by the District manager and operators would improve operations and accounting. In addition to physical improvements, it is anticipated that operational protocols would be developed in consultation with the Joint Board to better coordinate flow changes.

The primary operational outflow locations in BWGWD are the deliveries to the Gray Lodge Wildlife Area. The outflow locations are typically at the bottom end of primary or secondary laterals and therefore also include any operational spillage. The modernization project recommends installation of measurement at four primary outflow locations to better manage control structures, provide steadier deliveries to Gray Lodge (three different delivery locations), improve water accounting, and identify opportunities for reducing the spillage portion of the operation outflows.

Phase II System Modernization

Improved measurement and control at canal headings produces noticeable benefits if incoming flows can be effectively conveyed to the desired place of use. The second phase of modernization would improve key control points along the main supply canal between the headings and outflows to increase conveyance efficiency. This would include main canal water level control structures and lateral headings. Existing control sites may be abandoned in some cases, re-configured, retrofitted, downsized, or retained. The addition of Phase II improvements to Phase I improvements would generally provide steadier delivery of water from the main canal to laterals and turnouts, simplify operations by adding automation and increased the ability to make flow changes, and concentrate primary routing of flow fluctuations along the main canal.

In BWGWD (as in most open canal systems) the Belding Lateral contains flashboard check structures that require adjustment whenever there is a flow change to avoid impacts to deliveries to laterals and turnouts along the canal. Without adjustment, undesirable water level fluctuations can impact these flows. In addition to impacting service, these fluctuations present challenges to water accounting and may result in operators storing “extra water” in certain canal reaches as a buffer for when deficiencies occur. This water may ultimately spill if not needed.

Other than two lateral heading structures, all main canal primary control points that otherwise would be included for improvement under Phase II are scheduled for replacement under the Gray Lodge Wildlife Area Supply Project. This includes all lateral headings and check structures on the Belding Canal, Traynor Lateral, Schwind Lateral, and Cassady Lateral.

A key focus of the modernization process is to select how and where flow fluctuations in excess of demands should be routed through the system. Consolidation and routing of fluctuations along one primary route increases the likelihood that they can be used to meet downstream demand, and allows for simplified monitoring of system operations to inform adjustments to diversions and upstream structures to reduce spillage.

The Gray Lodge improvements establish the Belding Lateral as the primary spill route for the upper portion of the system and then to the Traynor Lateral for eventual delivery to Gray Lodge. Figure 1 provides an overview of site scheduled for improvement under the Gray Lodge project and those included in this modernization project.

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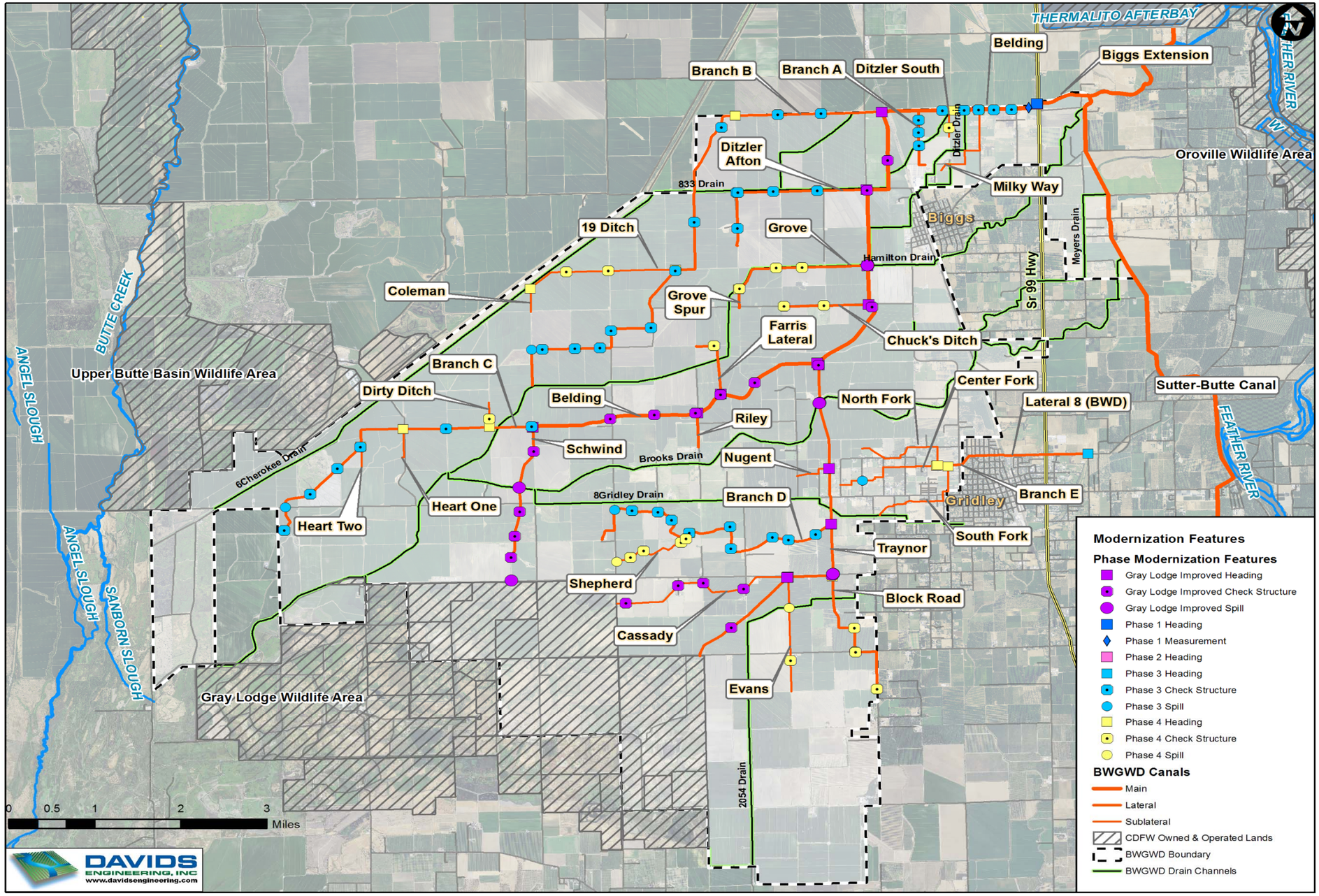

Figure 1. BWGWD System Modernization Phasing and Improvement Sites.

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Phase III System Modernization

The Phase II improvements to primary control points on the main canal would enable steadier flows to laterals and allow more flexible flow changes. To effectively extend this benefit to deliveries off of the laterals, Phase III would improve primary lateral control structures and primary end spills to improve control. Replacing existing check structures along the primary laterals with long crested weirs would provide constant upstream water levels with no adjustment required. Additionally, because of the long weir length, a small change in head corresponds to a large change in flow enabling more rapid transfer of flow fluctuations down the system because the required change in upstream pond storage to pass the change is minimized. Measurement is recommend to be installed at the end spills of all primary laterals to inform heading adjustment and monitoring general lateral operation.

Laterals that would be improved under Phase III include: Lateral 8, Branch A, Branch B, Branch C, Branch D, and Ditzler Afton.

Phase VI System Modernization

The fourth phase would build on lateral heading flow control completed under Phase II and Phase III, and lateral water level control completed under Phase III by improving secondary control points along laterals and sublateral control points to inform and improve operations. Additionally, minor or secondary safety spills are prioritized for improvement, although some intermediate safety spills would likely not be needed and could be abandoned as check structures are improved to allow routing of flow fluctuations without causing substantial water level fluctuations, capacities are increased, and the controllability of flows at heading structures is increased. Objectives are to increase flexibility, consistency, and adequacy of supply to sublaterals; increased delivery steadiness and consistency; and concentrating routing of flow fluctuations to a measurement location providing operators with feedback to help determine the status of deliveries or the need for a change at the lateral heading to improve operations. The fourth phase represents the final phase of system modernization to support spill reduction and possible diversion reduction, resulting in district-scale water conservation as well as increased levels of service.

The final phase would complete improvements to the following sublaterals: 19 Ditch, Milkway, Ditzler South, Shepherd, North Fork, South Fork, Center Fork, Grove, Grove Spur, Dirty Ditch, Coleman Ditch, Heart One Ditch, Heart Two Ditch, Chucks Ditch, and Farris Lateral.

Inventory of Existing Conditions

Existing conditions were characterized through consultation with District operations staff and digitally inventoried in tabular form and in an interactive mapping format. For each site type, representative sites were selected for field inspection to obtain dimensions, coordinates, photos and operational features typical of the site type to aid in strategy development and cost estimation. These sites included primary control points. Table 4 provides the site name, the site type, latitude, longitude, and a description of existing conditions for each site to be improved under the System Modernization project. Sites were assigned to one of the following categories: Inflow, Heading, Water Level Control, or Safety Spill. The system modernization plan described herein focuses on primary and secondary control points and other system components and may not be exhaustive.

Table 4. Inventory of Existing Conditions.

Site Name	Site Type	Latitude	Longitude	Description of Existing Conditions
Belding Heading	Heading	39.437	-121.689	Three, 4ft wide gear-operated rectangular undershot gates attached to concrete structure. Significant drop downstream of structure. Energy dissipation blocks are installed. 4ft wide spill weir adjacent to gates is used only in emergency situation and bypasses Belding Heading gates.
Belding Measurement	Flow Measurement	39.436	-121.690	Existing SonTek SL ADVM installed in natural channel cross section approximately 700 feet downstream from heading. Site may be affected by non-uniform velocities due to bend in canal just upstream.
Schwind End Spill	Spill	39.348	-121.804	Structural improvements being completed as part of the Gray Lodge Wildlife Area Water Supply Project.
Deliveries to Gray Lodge	Flow Measurement	Several Locations		Existing deliveries to Gray Lodge from Schwind, Traynor, and Cassady.
Branch A (Ditzler) Heading	Heading	39.437	-121.688	Concrete headwall with manually operated undershot gate
Lateral Headings, including: Branch B, Ditzler Afton, Grove, Chuck's Ditch, Traynor Lateral, Farris Lateral, Riley Lateral, Schwind Lateral, Nugent Lateral, Cassady Lateral, Evans Lateral, and Block Road Lateral				
Control structures along the following canals: Belding, Schwind, Traynor, and Cassady				
Evans Ditch Heading	Heading	39.348	-121.744	Concrete headwall with manually operated undershot gate
Block Road Ditch Heading	Heading	39.348	-121.735	Concrete headwall with several manually adjusted flashboard bays
Lateral 8 Heading	Heading	39.371	-121.679	Concrete headwall with manually operated undershot gate. Short section of pipe extends downstream from heading with outlet to open ditch.
Branch A weirs	Water Level Control	Several Locations		Concrete headwall structure with several manually operated flashboard bays
Branch B weirs	Water Level Control	Several Locations		
Branch D weirs	Water Level Control	Several Locations		
Branch C Weirs	Water Level Control	Several Locations		
Ditzler Afton Weirs	Water Level Control	Several Locations		
End Ashley Spill	Spill	39.392	-121.799	Concrete weir box with adjustable weir boards to control water level and spill point.
End Gerst Spill	Spill	39.361	-121.782	

Site Name	Site Type	Latitude	Longitude	Description of Existing Conditions
End Center Fork Spill	Spill	39.359	-121.724	
Hatch Spill	Spill	39.362	-121.853	
19 Ditch heading	Heading	39.406	-121.768	One 4ft wide canal gate at head of 42" diameter RCP that empties to earth lined canal. Acoustic Doppler meter installed near discharge end for measurement.
19 Ditch weirs	Water Level Control	Several Locations		Concrete headwall structure with several manually operated flashboard bays
Milkway Heading	Heading	39.436	-121.701	Concrete headwall with manually operated undershot gate. Short section of pipe extends downstream from heading with outlet to open ditch.
Ditzler South Heading	Heading	39.436	-121.707	
Shepherd Heading	Heading	39.356	-121.765	
North Fork heading	Heading	39.369	-121.711	Concrete headwall with two flashboard bays
South Fork heading	Heading	39.368	-121.709	Square concrete vault with manually operated undershot gate.
Center Fork Heading	Heading	39.369	-121.711	Concrete headwall with two flashboard bays
Grove Spur Heading	Heading	39.403	-121.754	Concrete headwall with 4ft wide rectangular slide gate with wheel operator
Dirty Ditch Heading	Heading	39.377	-121.809	Concrete headwall with manually operated undershot gate. Short section of pipe extends downstream from heading with outlet to open ditch.
Coleman Ditch Heading	Heading	39.403	-121.799	Concrete headwall with manually operated undershot gate.
Heart One Ditch Heading	Heading	39.377	-121.827	Concrete headwall with manually operated undershot gate. Short section of pipe extends downstream from heading with outlet to open ditch.
Heart Two Ditch Heading	Heading	39.374	-121.837	
Ditzler South Weirs	Water Level Control	Several Locations		Concrete headwall structure with several manually operated flashboard bays
Grove Weirs	Water Level Control	Several Locations		
Chucks Ditch Weirs	Water Level Control	Several Locations		
Farris Lateral Weirs	Water Level Control	Several Locations		
Block Road weirs	Water Level Control	Several Locations		
Evans Weirs	Water Level Control	Several Locations		

Site Name	Site Type	Latitude	Longitude	Description of Existing Conditions
Shepherd Weirs	Water Level Control	Several Locations		
Block Road Spill	Spill	39.334	-121.730	Concrete weir box with adjustable weir boards to control water level and spill point.
Evans Spill	Spill	39.342	-121.744	
End Shepherd Spill	Spill	39.351	-121.781	

System Modernization Physical and Operational Improvements

Level 1 and 2 Improvements

Each phase includes individual sites selected and evaluated based on the strategy described in the preceding paragraphs. For each site, improvement is split into two levels, Level 1 and Level 2. Level 1 improvements typically include fundamental infrastructure and measurement enhancements that are manually operated or read, or locally automated, and designed as SCADA-Ready[6]. These improvements include, but not limited to new, manually adjustable heading gates; long crested weirs; locally automated overshot gates; and measurement devices such as weirs, acoustic Doppler flow meters, and propeller meters. Level 2 improvements build upon Level 1 improvements by automating certain additional features, adding electronic sensors, installing on-site digital display of flow rate or other parameters, or adding remote monitoring or control through a Supervisory Control and Data Acquisition System (SCADA). Level 1 improvements are stand-alone, while Level 2 improvements generally require Level 1 to be completed prior to or at the same time. The progression from level 1 to level 2 improvements provides the flexibility to complete Level 1 (which has significant benefits on its own) while assessing the benefits of SCADA, further prioritizing sites, establishing a SCADA base station, and gradually implementing potentially more complex and technically intricate remote control sites.

Although Level 2 is not universally required to be completed to obtain significant benefits, several sites would substantially benefit. Two examples of this are:

1. Remotely located end spill sites not frequently visited by operators. Remote monitoring would reduce travel time potentially enabling additional flow changes, as needed.
2. Automated flow control gates at headings with substantial upstream water level fluctuations; however, assuming water level control structures are installed, the flow control device could have little additional benefit until remote control is added to allow for flow adjustments.

In some cases, there could be capital cost savings by completing Level 1 and Level 2 improvements at the same time.

[6] "SCADA-Ready" describes a package of hardware and/or software that communicates and operates locally but has been specifically designed and installed to readily accept a data transmission and receiving device (e.g. radio, cellular modem, etc.) and to provide remote communication with an established base station and SCADA human machine interface (HMI).

Table 5 provides a description of the improvements proposed for each site, the objective of the improvements and estimated Phase 1 and Phase 2 improvement costs. For each site and level of improvements, upfront capital costs and annualized capital, operations, and maintenance costs are provided. All costs are subject to revision following refinement of site improvements as informed by more detailed review and design.

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Table 5. Site Improvement Matrix.

Site Name	Site Type	Description of Operational Objective with Improvements	Level 1 Modernization and Enhancement	Capital Cost ($)	Annual Cost ($/yr)	Level 2 Modernization and Enhancement	Capital Cost ($)	Annual Cost ($/yr)
SCADA Office Base Station		Allows remote monitoring of measured parameters at SCADA equipped sites. Also allows remote control and adjustment of set points at automated water level or flow control sites. Provides for storage of data and interface for developing comprehensive status reports, usage statistics, and monitoring information for improved water management, accounting and reporting.	Level 1 Modernization and Enhancement does not include SCADA at sites; therefore, base station is not required.	$0	$0	Furnish and install one desktop personal computer, including: processor, monitor, keyboard, mouse, drivers, USB, RS232, Ethernet, communication ports, cables, adapters, modems, printer, operating system software and HMI software. Base station spread spectrum radio, mast, and antenna for communication with remote sites. Five hardened laptops and vehicle mounts for operator/in-field use. Vehicle-mounted radios and antennas for remote communications and monitoring of sites.	$138,063	$17,039
Spare Equipment		Minimize down time associated with simple equipment maintenance or malfunctions and/or procurement of site or system specific hardware.	Small inventory of site and system specific equipment that is critical for proper operation of improvements.	$23,692	$2,913		$0	$0
Phase 1 Modernization - Improvement of Primary Inflow Locations and Primary Operational Outflow Locations								
Belding Heading	Heading	Provide reliable deliveries to Biggs West Gridley Water District and Gray Lodge Wildlife Area.	See 'Belding Measurement' Improvements below. Add digital flow display at gates to enable informed adjustments.	$2,220	$122	See Joint Board Improvements. Replace existing undershot gates with automated upstream water level control gate(s). Gates would maintain u/s water level for Minderman Delivery and pass any fluctuations to Gray Lodge.	$847,400	$46,712
Belding Measurement	Flow Measurement	Provide measurement of delivered flow to Biggs West Gridley to allow operators to make more informed adjustments and to improve water accounting	Perform velocity index calibration on existing ADVM and improve access bridge. Relocate meter further downstream as needed for accuracy.	$55,400	$5,300	Add communication hardware to site and integrate with SCADA system to allow real-time monitoring of flow rates, water depths and sensor parameters.	$5,900	$600
Schwind End Spill	Spill	Provide accurate and accessible measurement of spillage flow rate from the lateral as feedback loop on heading operation, general lateral operation, and District water accounting.	Replace weir box with new. Install sharp crested weir plate and mount custom staff gage calibrated to report spill flow rate based on the depth of water above the weir crest.	$8,700	$700	Install pressure transducer in new stilling well upstream of spill box to measure head on weir. Perform calibration of weir. Install communication hardware and integrate with SCADA system to allow remote monitoring.	$15,400	$1,500
Deliveries to Gray Lodge	Flow Measurement	Provide accurate and accessible measurement of flow rate to Gray Lodge Wildlife Area as feedback loop on heading operation, general lateral operation, and District water accounting.	Install ADVM in stable section of existing channels of the Traynor, Cassady, and Schwind Laterals. Install solar power system, digital flow display, and related components. Perform velocity index calibration of measurement site. Site will be SCADA-Ready.	$79,200	$8,700	Add communication hardware to site and integrate with SCADA system to allow real-time monitoring of flow rates, water depths and sensor parameters.	$17,700	$1,800
Phase 2 Modernization - Improvement of Main Canal Primary Control Points								
Branch A (Ditzler) Heading	Heading	Provide accurate, repeatable and consistent flow to supply deliveries downstream of the lateral heading.	Perform stream gaging at various flows to calibrate existing chart recorder. Add gaging bridge to facilitate periodic verification.	$15,000	$822	None	$11,800	$1,200
Lateral Headings, including: Branch B, Ditzler Afton, Grove, Chuck's Ditch, Traynor Lateral, Farris Lateral, Riley Lateral, Schwind Lateral, Nugent Lateral, Cassady Lateral, Evans Lateral, and Block Road Lateral			All listed sites are included for modernization under the Gray Lodge Wildlife Area Water Supply Project. Phase 1B of this project was completed in May 2014.					
Control structures along the following canals: Belding, Schwind, Traynor, and Cassady								
Block Road Ditch Heading	Heading	Provide accurate, repeatable and consistent flow to supply deliveries downstream of the lateral heading.	Replace existing flashboard bays with new concrete heading, undershot gate and section of pipe downstream. Install ADVM downstream from gates. Add digital flow display near gate operators.	$49,600	$4,500	Install communication hardware and integrate site with SCADA system to allow remote monitoring.	$5,900	$600
Phase 3 Modernization - Improvement of Lateral Primary Control Points and Spill Routing								

Site Name	Site Type	Description of Operational Objective with Improvements	Level 1 Modernization and Enhancement	Capital Cost ($)	Annual Cost ($/yr)	Level 2 Modernization and Enhancement	Capital Cost ($)	Annual Cost ($/yr)
Lateral 8 Heading	Heading	Provide accurate, repeatable and consistent flow to supply deliveries downstream of the lateral heading.	See BWD Improvements. Install weir box on downstream end of existing pipe at heading and install open channel propeller meter. Replace heading gate as necessary to provide adjustable and reliable control. Site will be SCADA-Ready.	$26,400	$2,400	Replace existing gate and structure with new automated flow control gate. Install communication hardware and integrate with SCADA system to allow remote monitoring and control of gate function and set points.	$11,800	$1,200
Branch A weirs	Water Level Control	Maintain constant upstream deliveries by maintaining the desired upstream water level in the supply canal over a range of canal flow rates. Simplify operations by reducing the need to add or remove flashboards, and increase the rate at which flow changes can be passed through the system	Replace eight existing check structures with LCWs.	$177,600	$11,200	None	$0	$0
Branch B weirs	Water Level Control		Replace ten existing check structures with LCWs.	$531,000	$34,000	None	$0	$0
Branch D weirs	Water Level Control		Replace six existing check structures with LCWs.	$245,400	$15,600	None	$0	$0
Branch C Weirs	Water Level Control		Replace seven existing check structures with LCWs.	$371,700	$23,800	None	$0	$0
Ditzler Afton Weirs	Water Level Control		Replace five existing check structures with LCWs.	$111,000	$7,000	None	$0	$0
End Ashley Spill	Spill	Provide accurate and accessible measurement of spillage flow rate from the lateral as feedback loop on heading operation, general lateral operation, and District water accounting.	Replace weir box with new. Install sharp crested weir plate and mount custom staff gage calibrated to report spill flow rate based on the depth of water above the weir crest.	$8,700	$700	Install pressure transducer in new stilling well upstream of spill box to measure head on weir. Perform calibration of weir. Install communication hardware and integrate with SCADA system to allow remote monitoring.	$15,400	$1,500
End Gerst Spill	Spill			$8,700	$700		$15,400	$1,500
End Center Fork Spill	Spill			$8,700	$700		$15,400	$1,500
Hatch Spill	Spill			$8,700	$700		$15,400	$1,500
Phase 4 Modernization - Improvement of Lateral Secondary Points, Sublateral Control Points and Secondary Spill Points								
19 Ditch heading	Heading	Provide accurate, repeatable and consistent flow to supply deliveries downstream of the lateral heading.	Update existing ADVM with newer model. Install solar power system and add digital flow rate display near meter. Site will be SCADA-Ready	$26,400	$2,900	Add communication hardware to site and integrate with SCADA system to allow real-time monitoring of flow rates, water depths and sensor parameters.	$5,900	$600
19 Ditch weirs	Water Level Control	Maintain constant upstream deliveries by maintaining the desired upstream water level in the supply canal over a range of canal flow rates. Simplify operations by reducing the need to add or remove flashboards, and increase the rate at which flow changes can be passed through the system	Replace two existing check structures with LCWs.	$44,400	$2,800	None	$0	$0
Milkway Heading	Heading	Provide accurate, repeatable and consistent flow to supply deliveries downstream of the lateral heading.	Install weir box on downstream end of existing pipe and install open channel propeller meter. Install trash rack at inlet. Replace heading gate as necessary to provide adjustable and reliable control. Site will be SCADA-Ready.	$26,400	$2,400	Install communication hardware and integrate with SCADA system to allow remote monitoring.	$11,800	$1,200
Ditzler South Heading	Heading			$26,400	$2,400		$11,800	$1,200
Shepherd Heading	Heading			$26,400	$2,400		$11,800	$1,200
North Fork heading	Heading	Provide accurate, repeatable and consistent flow to supply deliveries downstream of the lateral heading.	Replace existing flashboard bays with undershot gates. Install upstream and downstream staff gages relative to local datum to provide calculation of head across gate. Develop relationship for gate opening and flow rate at various heads by performing current metering downstream.	$15,100	$827	Install Rubicon Sonoray Acoustic Doppler flow meter boxes upstream of existing gates. Add solar power system, communication hardware and integrate with SCADA system to allow monitoring of flow rate.	$17,000	$931
South Fork heading	Heading		Install weir box on downstream end of existing pipe and install open channel propeller meter. Install trash rack at inlet. Replace heading gate as necessary to	$26,400	$2,400	Install communication hardware and integrate with SCADA system to allow remote monitoring.	$11,800	$1,200

Site Name	Site Type	Description of Operational Objective with Improvements	Level 1 Modernization and Enhancement	Capital Cost ($)	Annual Cost ($/yr)	Level 2 Modernization and Enhancement	Capital Cost ($)	Annual Cost ($/yr)
			provide adjustable and reliable control. Site will be SCADA-Ready.					
Center Fork Heading	Heading		Replace two bay weir structure with long crested weir. Calculate flow by difference. All fluctuations in Lateral 8 will pass over weir and to end spill, thus maintaining upstream water level for constant delivery.	$40,900	$2,600		$0	$0
Grove Spur Heading	Heading		Install weir box on downstream end of existing pipe at heading and install open channel propeller meter. Install trash rack on inlet. Replace heading gate as necessary to provide adjustable and reliable control. Site will be SCADA-Ready.	$26,400	$2,400		$11,800	$1,200
Dirty Ditch Heading	Heading			$26,400	$2,400		$11,800	$1,200
Coleman Ditch Heading	Heading		Replace existing flashboard bays with new concrete heading, undershot gate and section of pipe downstream. Install weir box on downstream end of existing pipe at heading and install open channel propeller meter. Install trash rack on inlet.	$26,400	$2,400		$11,800	$1,200
Heart One Ditch Heading	Heading		Install weir box on downstream end of existing pipe at heading and install open channel propeller meter. Install trash rack at inlet. Replace heading gate as necessary to provide adjustable and reliable control. Site will be SCADA-Ready.	$26,400	$2,400	Install communication hardware and integrate with SCADA system to allow remote monitoring.	$11,800	$1,200
Heart Two Ditch Heading	Heading			$26,400	$2,400		$11,800	$1,200
Ditzler South Weirs	Water Level Control	Maintain constant upstream deliveries by maintaining the desired upstream water level in the supply canal over a range of canal flow rates. Simplify operations by reducing the need to add or remove flashboards, and increase the rate at which flow changes can be passed through the system	Replace one existing check structure with a LCW.	$40,900	$2,600	None	$0	$0
Grove Weirs	Water Level Control		Replace three existing check structures with LCWs.	$66,600	$4,200	None	$0	$0
Chucks Ditch Weirs	Water Level Control		Replace two existing check structures with LCWs.	$44,400	$2,800	None	$0	$0
Farris Lateral Weirs	Water Level Control		Replace one existing check structure with a LCW.	$22,200	$1,400	None	$0	$0
Block Road weirs	Water Level Control		Replace three existing check structures with LCWs.	$159,300	$10,200	None	$0	$0
Evans Weirs	Water Level Control		Replace one existing check structure with a LCW.	$53,100	$3,400	None	$0	$0
Shepherd Weirs	Water Level Control		Replace two existing check structure with a LCW.	$44,400	$2,800	None	$0	$0
Block Road Spill	Spill	Provide accurate and accessible measurement of spillage flow rate from the lateral as feedback loop on heading operation, general lateral operation, and District water accounting.	Replace weir box with new. Install sharp crested weir plate and mount custom staff gage calibrated to report spill flow rate based on the depth of water above the weir crest.	$8,700	$700	Install pressure transducer in new stilling well upstream of spill box to measure head on weir. Perform calibration of weir. Install communication hardware and integrate with SCADA system to allow remote monitoring.	$15,400	$1,500
Evans Spill	Spill			$8,700	$700		$15,400	$1,500
End Shepherd Spill	Spill			$8,700	$700		$15,400	$1,500

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System Modernization Costs

The total combined cost (all phases, Level 1 and Level 2) of system modernization is estimated to be approximately $3,682,000, with annualized estimated costs of $254,000. Individual costs by modernization phase range from a low of $82,000 to a high of $1,571,000 for Phase 2 and Phase 3, respectively. Costs are further summarized in Table 6. Additionally, the costs of a SCADA base station and mobile operator terminals that would form the backbone of the District SCADA system have been estimated, along with the cost of spare equipment to be kept on hand to repair or replace individual site components due to theft, vandalism, or other failure. The cost of the office base station may be drastically reduced, or eliminated, if the District is able to 'piggy-back' on to and expand the existing SCADA network current owned and operated by the Joint Water Districts Board.

Table 6. Summary of Estimated Capital and Annualized Costs.

	Level 1		Level 2	
Modernization Phase	**Capital Cost ($)**	**Annual Cost ($/yr)**	**Capital Cost ($)**	**Annual Cost ($/yr)**
Phase I - Improvement of Primary Inflow Locations and Primary Operational Outflow Locations	$145,520	$14,822	$886,400	$50,612
Phase II - Improvement of Main Canal Primary Control Points	$64,600	$5,322	$17,700	$1,800
Phase III - Improvement of Lateral Primary Control Points and Spill Routing	$1,497,900	$96,800	$73,400	$7,200
Phase IV - Improvement of Lateral Secondary Points, Sublateral Control Points and Secondary Spill Points	$821,400	$60,227	$175,300	$16,831
Total Cost =	$2,529,420	$177,170	$1,152,800	$76,444
SCADA Office Base Station	-	-	$138,063	$17,039
Spare Parts	$23,692	$2,913		-

Potential Benefits

The system modernization plan described herein represents comprehensive improvements of the district's distribution system, adding several automated control structures, improved measurement, new heading structures, re-regulation points, and SCADA. Flow paths targeted under of the system modernization project are:

- Operational spillage
- Tailwater
- Drainage outflows
- Deliveries
- Diversions

Improvements would allow reduced operational spillage and reduced deliveries due to increased delivery efficiency, which would reduce on-farm tailwater and, in some cases, deep percolation. Reduced deliveries result in reduced diversions, which results in corresponding reductions in spillage and drainage outflows. Available water not diverted remains in storage and could potentially be

available for transfer or to meet local unmet demands. Additionally, water quality benefits may occur through reduced tailwater outflow.

Through implementation of the complete system modernization program (Phases I to IV and Levels 1 and 2), it is estimated that approximately 20 to 50 percent[7] of existing operational spillage could be conserved annually, or between approximately 2,000 and 5,000 af per year. This conserved water could be used to:

- Increase local water supply,
- Increase local water delivery flexibility,
- Increase in-stream flow, and/or
- Improve water quality

Each phase provides varying levels of anticipated benefit with the first two phases likely seeing higher benefit than the third and fourth due to the greater number of sites improved, establishment of primary spill routing, and improvement of control structures that are located higher in the system (i.e. have control over a larger proportion of the total water diverted). The marginal estimated range of percent reduction in spillage and boundary outflow achieved by completing phases is described below:

1. Phase I: 4 to 10 percent reduction; 400 to 1,000 af of the targeted flowpaths
2. Phase II: 1 to 2 percent reduction; 100 to 200 af of the targeted flowpaths
3. Phase III: 10 to 25 percent reduction; 1,000 to 2,500 af of the targeted flowpaths
4. Phase IV: 5 to 13 percent reduction; 500 to 1,300 af of the targeted flowpaths

In order to realize the estimated reductions in spillage or boundary outflow noted above for each phase, it would be necessary to implement all phases that are numerically lower to some degree.

Net Benefit Analysis

The District is currently implementing associated EWMPs at locally cost-effective levels. The cost of additional surface water supplies has been approximately $5 per acre-foot in recent years. The estimated implementation cost per unit of water conserved is presented in Table 7. In the table, annualized costs of the SCADA base station are distributed across phases based on the relative magnitude of annualized costs for each phase. Currently, the unit cost of conservation exceeds the potential monetary savings. As a result, further implementation of the system modernization project is not locally cost effective at this time. In the future, it is anticipated that the costs and estimated benefits of this improvement project will be evaluated as additional information becomes available.

[7] Based on estimated percent reductions in spillage for various improvement measured listed in the technical memorandum "Spillage Reduction- Monitoring and Verification" published by the Agricultural Water Management Council, local conditions, experience, and judgment. Limited reductions in tailwater may occur to some degree based on improved delivery steadiness, flow measurement, and control.

Table 7. Estimated Implementation Cost per Unit of Water Conserved.

Modernization Phase	Annual Cost, Levels 1 and 2 ($/yr)	Conserved Water Range (af/yr)	Conservation Cost ($/af)
Phase I - Improvement of Primary Inflow Locations and Primary Operational Outflow Locations	$70,582	400 to 1,000	$71 to $176
Phase II - Improvement of Main Canal Primary Control Points	$7,682	100 to 200	$38 to $77
Phase III - Improvement of Lateral Primary Control Points and Spill Routing	$112,182	1,000 to 2,500	$45 to $112
Phase IV - Improvement of Lateral Secondary Points, Sublateral Control Points and Secondary Spill Points	$83,121	500 to 1,300	$64 to $166
Totals	$273,567	2,000 to 5,000	$55 to $137

Project 2: Boundary Outflow and Primary Spill Measurement and Drain Water Recovery Project

Project Description

Two improvement packages are described in this section: Boundary Flow and Primary Spill Measurement, and Drain Water Recovery. Both of these projects have similar objectives, as described in Table 8.

Table 8. Objectives of Boundary Outflow and Primary Spill Measurement and Drain Water Recovery Projects.

Objective	Boundary Flow and Primary Spill Measurement	Drain Water Recovery
Improve Water Use Efficiency	Measurement of operational spillage and drainage flows can be used to make better informed system adjustments that can lead to reduced spillage and possibly a reduction in total demands. Reduced spillage and reduced tailwater can lead to reduced diversions.	Reuse of operational spillage and tailwater results in decreased required diversions. Available water not diverted remains in storage and could potentially be availableto meet unmet demands or for transfer.
Develop Water Use Data	Measurement of boundary outflows and primary spillage provides the data necessary to quantify surface water leaving district, better define unmeasured flows (such as deep percolation), determine areas of high loss, characterize operational efficiencies, and aid in prioritization of improvements.	
Support Reporting	Measurement of spillage, boundary flows and recovered drainwater provides information relating to water supply, water use, water quality, environmental benefits, etc. Measurement also supports the district in responding to potential inquiries from landowners regarding water supply, water use, and historical trends.	
Increase Operational Efficiency	Measurement of spillage enables operators to make corresponding adjustments at lateral headings or at the diversion to reduce spillage or total diversions. Measurement provides early detection of end canal conditions (high or low) that may be impacting delivery service.	Recovering drain water enables operators to meet demands more quickly and flexibly. Measurement will inform adjustments, maximizing drainwater extraction, minimizing diversions and minimizing spillage.

The project summaries provided in this attachment include an inventory of existing or potential sites that fall into one of the classifications described in Table 9.

Table 9. Site Type Classifications.

Site Type Classification	Description	Improvement Package
Boundary Inflow	Flows entering the District boundaries and providing the availability of increased supply.	Boundary Flow and Primary Spill Measurement
Boundary Outflow	Flows leaving the District boundaries and representing excess inflows, intentional releases to satisfy obligations to meet out-of-District demands, or water management issues.	Boundary Flow and Primary Spill Measurement
Internal Outflow	Flows intentionally discharged from District canals to drainage channels for downstream delivery or possible recapture (e.g. deliveries to Secondary).	Boundary Flow and Primary Spill Measurement
Internal Inflow	Additional supply entering the District from within its boundaries. (e.g. groundwater wells).	Boundary Flow and Primary Spill Measurement
Internal Spill	Excesses in supply canals that are discharged to drain channels through safety spill structures.	Boundary Flow and Primary Spill Measurement
Drain Water Recovery (Pump)	Recapture of drain water via pump as it passes through the District. Recaptured water may be spillage or tailwater from neighboring Districts, or from internal sources.	Drain Water Recovery

For each selected site, conceptual designs were developed that improve the site to meet the objectives. A total of four boundary outflow locations, eight internal spill sites, and six drain water recovery sites were identified for improvement under these two improvement packages. The selected sites (shown in Figure 2) were identified as high priority through consultation with District personnel or identified has likely high use sites based on their position in the distribution system, such as at the end of main canals or primary laterals. Several additional spill sites were identified but not included in this improvement package because of their perceived low volume or infrequent use. Recommended improvement sites are subject to revision following refinement of prioritization criteria and more detailed review and analysis.

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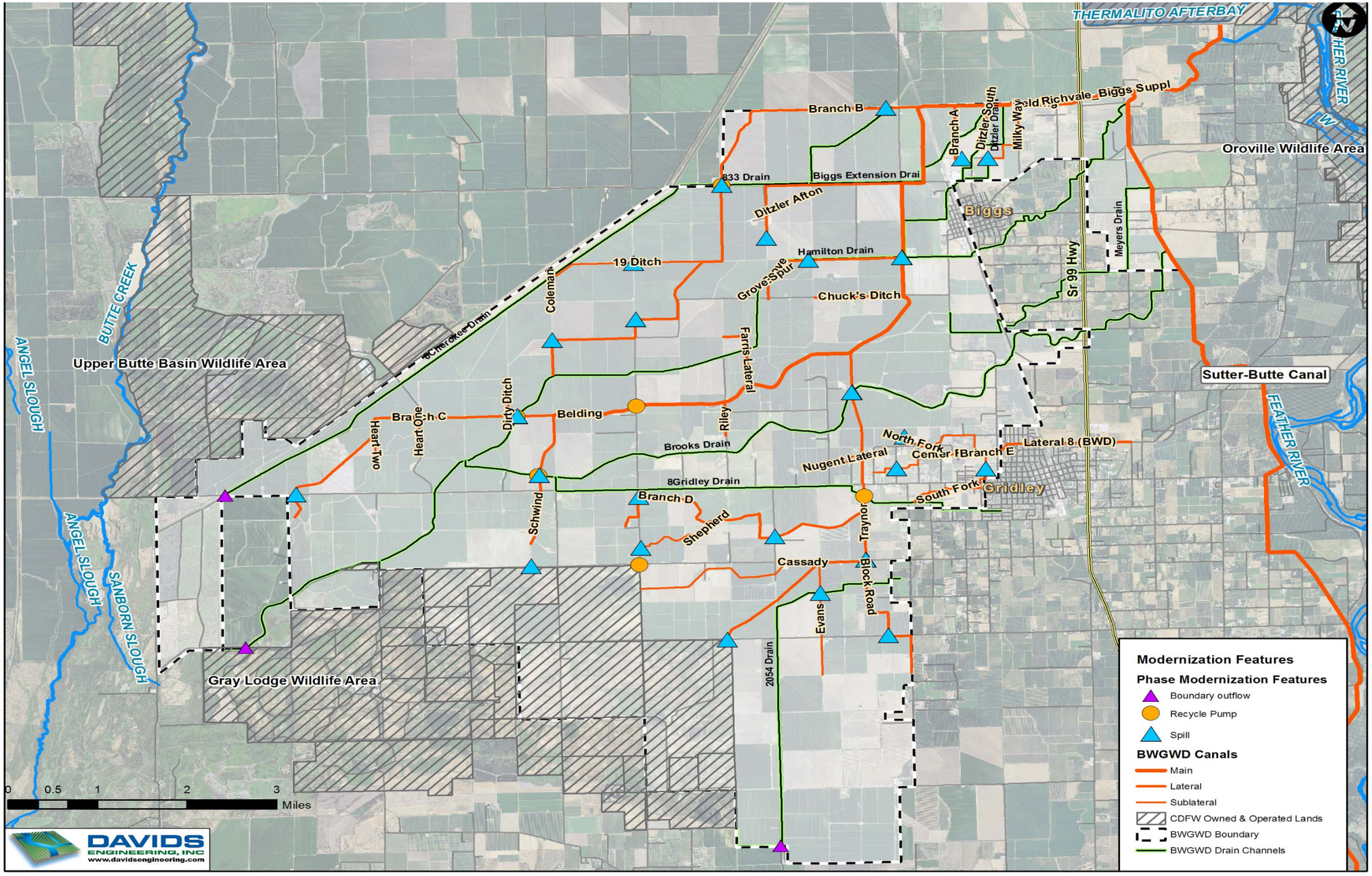

Figure 2. BWGWD Boundary Outflow, Primary Spills and Drain Water Recovery Sites.

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Recommended measurement devices for the boundary and spill flows vary by site type, site conditions and existing infrastructure or proposed infrastructure. Additionally, the intensity of use (rate and duration) relative to other sites, and the importance of the site to meeting the objectives also factor into the selection of measurement devices. In total, four measurement strategies were developed based on unique conditions. In general, it is recommended that improvement projects or phased modernization employ the same device, or a limited selection of devices, throughout the District to maintain consistency in reporting, accuracy, and operations. This also simplifies training of new employees, maintenance protocols, and troubleshooting, as well as minimizes the required spare parts. The four measurement strategies are described in Table 10.

Table 10. Descriptions of Measurement Devices and Associated Advantages and Limitations.

Measurement Device	Measurement Method	Advantages	Limitations
Acoustic Doppler Meter	Doppler technology measures water velocity. Velocity X Area = Flow rate	High accuracy depending on siting. Generally little calibration and are SCADA-Ready. No moving parts.	Requires power source. Requires a stable cross section and uniform flow velocities. Weeds or other obstructions impact accuracy.
Open Channel Propeller Meter	Flow through pipe rotates propeller. Rotational velocity is related to water velocity. Velocity X Area = Flow rate	Simple and relatively inexpensive device. Can provide good accuracy depending on siting. Effective in submerged situations. District staff is familiar with technology.	Air pockets, turbulence, weeds or other trash may cause inaccuracies. Moving parts require annual maintenance. Requires full pipe.
Sharp Crested Weir	For a given weir length, flow is determined by depth of flow over weir crest.	Simple and inexpensive device. Easily adaptable to majority of existing spill structures. Good accuracy depending on siting. Minimal maintenance required.	Accuracy limited to measurement of head on weir. Requires free fall of flow over weir and uniform velocities.
RemoteTracker[8]	Portable device measures water velocity in pipeline. Velocity X Area = Flow rate	Portable. Highly accurate and simple operation. Incorporates remote communications and water delivery records.	Subject to inaccuracies caused by air pockets or turbulence. Requires full pipe. Unit cost is high. Does not provide continuous measurement.

Measurement of drain channels often presents unique challenges not often experienced in distribution canals. These include, but are not limited to: inconsistent cross sections with heavy vegetative growth, widely fluctuating flows including storm water runoff, are not typically maintained, higher than normal trash loads, below grade, low hydraulic gradients, and may be subject to additional environmental regulations.

Drain water recovery improvement recommendations focus on providing a reliable and flexible supply that can be monitored by the operators and manipulated when needed. The amount of drain water

[8] The RemoteTracker is a portable measurement device developed specifically as a water district delivery measurement solution in response to State of California Senate Bill x7-7. The device is currently being utilized by some Feather River water users.

recovery is limited to available drain flows, but improvements seek to maximize its use. Effective recovery sites require: 1) infrastructure to check-up drain flows for extraction, 2) extraction device with flexible control, 3) monitoring and measurement of extraction, and 4) infrastructure or equipment in canal to provide feedback for control logic and pass recovered water to deliveries.

Drain recovery sites identified are all existing sites currently used to varying degrees for drain water extraction.

Several of the boundary flow, spills, and drain water recovery sites are incorporated to some degree in the Modernization package as measurement of outflows is a critical component, as is reregulation and augmentation of supplies using drain water. There are several spill sites recommended for improvement in this package that are not included in the modernization package. This is because the modernization package helps define new spill routing opportunities and consolidates multiple spill sites or eliminates the need for intermediate operational spills, other than in emergency situations.

In most cases, selected spill sites are existing sites that require only minimal improvement or slight reconfiguration; however, some require complete reconstruction or new measurement method. Boundary outflow and internal outflow sites are generally new sites, but their locations are defined at the crossing of the District boundary by the conveyance channel. These sites may require the modification of the site for flow measurement accuracy or installation of the measurement device. Drain water recovery sites are all historical drain recovery sites that either need refurbishment or redesign, or flow measurement and remote monitoring. Where possible, extraction of drain water using gravity is generally the most cost effective solution; however, no such sites were identified in BWGWD.

Inventory of Existing Sites

Existing sites were identified through consultation with District operations staff and digitally inventoried in tabular form and in an interactive mapping format. For each site type, several sites were selected for field inspection to obtain dimensions, coordinates, photos and operational features typical of the site type to aid in strategy development and costing. For each site proposed for improvement, Table 11 provides the site name, the site type, latitude, longitude, and a description of the existing conditions. As previously discussed, the improvement process described here focuses on primary outflow and spill points and drain water recovery sites and may not include all minor features.

Table 11. Inventory of Existing Sites.

Site Name	Site Type	Latitude	Longitude	Description of Existing Conditions
Snake Creek	Boundary Outflow	Location for Installation to be Determined		Wide and deep incised channel with heavily vegetated embankments
Hamilton Slough	Boundary Outflow			Wide and deep incised channel with heavily vegetated embankments
Cherokee Canal	Boundary Outflow			Wide and deep incised channel with heavily vegetated embankments
Deliveries to Gray Lodge	Flow Measurement	Several Locations		Existing deliveries to Gray Lodge from Schwind, Traynor, and Cassady.
Schwind End Spill	Spill	39.348	-121.804	Structural improvements being completed as part of the Gray Lodge Wildlife Area Water Supply Project.
End Ashley Spill	Spill	39.392	-121.799	Concrete weir box with adjustable weir boards to control water level and spill point.
End Gerst Spill	Spill	39.361	-121.782	
End Center Fork Spill	Spill	39.359	-121.724	
Hatch Spill	Spill	39.362	-121.853	
Block Road Spill	Spill	39.334	-121.730	Concrete weir box with adjustable weir boards to control water level and spill point.
Evans Spill	Spill	39.342	-121.744	
End Shepherd Spill	Spill	39.351	-121.781	
Redwood Recycle Pumps	Drain Water Recovery	39.377	-121.807	Two pumps (50hp and 20hp) pump from Hamilton Drain to augment supply in Green Lateral. Pumps discharge downstream of flume. Both pumps are manually operated.
A-Line Recycle Pumps	Drain Water Recovery	39.421	-121.763	One pump (30hp) pumps approximately 25cfs from the RD833 Drain to the Ashley Lateral. Pump discharges through 24"diameter pipe and is operated manually.
Schwind Recycle Pumps	Drain Water Recovery	39.365	-121.802	Two pumps (20 and 40hp), two 24" diameter discharge pipes downstream of Schwind flume (6' wide with two 4' flashboard bays). 48" CMP road crossing immediately u/s from flume. Pumps run manually. Schwind dam doesn't appear to be functional (other than maybe a restriction)
Ackinson Recycle Pumps	Drain Water Recovery	39.361	-121.735	15hp pump discharges to canal via 15" diameter steel pipe with flapper valve at end. Discharge pipe = 40ft long
Owen's Pumps	Drain Water Recovery	39.379	-121.782	Three pumps (all 20hp) pump a maximum of 30cfs from the Hamilton Ditch via an extension canal and discharge into the Green Lateral via three 18" diameter pipes.
Bilbo Pumps	Drain Water Recovery	39.348	-121.782	10hp pump (5cfs capacity) pumps water from drain to Gray Lodge. Water is diverted through culvert to sump where it is pumped to open ditch

Boundary Outflow and Spill Measurement and Drain Water Recovery Physical and Operational Improvements

The two improvement packages include sites selected based on strategies described in the preceding paragraphs. For each site, improvement is split into two levels, Level 1 and Level 2. Level 1 improvements often are infrastructure and measurement enhancements that are manually operated or read, but designed as SCADA-Ready[9] sites. These improvements include, but not limited to: VFD-controlled pumps, automated gates, measuring weirs, acoustic Doppler meters, propeller meters, and RemoteTracker devices. Level 2 improvements build on the Level 1 improvements by adding electronic sensors, installing on-site digital display of flow rate or other parameters, or add remote monitoring or control through a Supervisory Control and Data Acquisition System (SCADA). Level 1 improvements are stand-alone, while Level 2 improvements generally require Level 1 to be completed prior or simultaneously. This phased implementation provides the District the flexibility to complete Level 1 (which has significant benefits on its own) while assessing the benefits of SCADA, prioritizing sites, establishing the SCADA base station and gradually implement the more complex or more expensive sites.

Although Level 2 is not universally required to be completed to obtain significant benefits, several sites will greatly benefit from it. For example, remotely located end spill sites or boundary outflow sites are not frequently visited by operators, and if they are visited and spill is noticed, it may not be worth the travel time to the heading to make a change. Remote monitoring would eliminate travel time, but does require the development of a SCADA office base station.

Additionally, in some cases, there is potentially some savings in capital costs by completing level 1 and level 2 at the same time.

Table 12 provides a description of the improvement proposed for each Boundary Flow and Primary Spill sites, the objective of the improvement and a Phase 1 and Phase 2 cost. Table 13 provides similar detail for Drain Recovery Sites. All costs are subject to revision following refinement of site improvements following more detailed review and design.

[9] "SCADA-Ready" describes a package of hardware and/or software that communicates and operates locally but has been specifically designed and installed to readily accept a data transmission and receiving device (e.g. radio, cellular modem, etc.) and to provide remote communication with an established base station and SCADA human machine interface (HMI).

Table 12. Summary of Boundary Outflow and Primary Spill Measurement Improvement Sites.

Site Name	Site Type	Description of Operational Objective	Level 1 Modernization and Enhancement	Capital Cost ($)	Annual Cost ($/yr)	Level 2 Modernization and Enhancement	Capital Cost ($)	Annual Cost ($/yr)
Snake Creek	Boundary Outflow	Measurement of boundary outflows will assist BWGWD operators in day to day and seasonal adjustments and improve water accounting within the service area.	Install ADVM in stable section of existing drain channel. Install solar power system, digital flow display, and related components. Perform velocity index calibration of measurement site. Site will be SCADA-Ready.	$22,900	$2,206	Add communication hardware to site and integrate with SCADA system to allow real-time monitoring of flow rates, water depths and sensor parameters.	$5,900	$600
Hamilton Slough	Boundary Outflow			$22,900	$2,206		$5,900	$600
Cherokee Canal	Boundary Outflow			$22,900	$2,206		$5,900	$600
Deliveries to Gray Lodge	Flow Measurement	Provide accurate and accessible measurement of flow rate to Gray Lodge Wildlife Area as feedback loop on heading operation, general lateral operation, and District water accounting.	Construct stable and uniform cross section in existing canal cross section and install ADVM. Install solar power system, digital flow display, and related components. Perform velocity index calibration of measurement site. Site will be SCADA-Ready.	$79,200	$8,700	Add communication hardware to site and integrate with SCADA system to allow real-time monitoring of flow rates, water depths and sensor parameters.	$17,700	$1,800
Schwind End Spill	Spill	Provide accurate and accessible measurement of spillage flow rate from the lateral as feedback loop on heading operation, general lateral operation, and District water accounting.	Replace weir box with new. Install sharp crested weir plate and mount custom staff gage calibrated to report spill flow rate based on the depth of water above the weir crest.	$8,700	$700	Install pressure transducer in new stilling well upstream of spill box to measure head on weir. Perform calibration of weir. Install communication hardware and integrate with SCADA system to allow remote monitoring.	$15,400	$1,500
End Ashley Spill	Spill	Provide accurate and accessible measurement of spillage flow rate from the lateral as feedback loop on heading operation, general lateral operation, and District water accounting.	Replace weir box with new. Install sharp crested weir plate and mount custom staff gage calibrated to report spill flow rate based on the depth of water above the weir crest.	$8,700	$700	Install pressure transducer in new stilling well upstream of spill box to measure head on weir. Perform calibration of weir. Install communication hardware and integrate with SCADA system to allow remote monitoring.	$15,400	$1,500
End Gerst Spill	Spill			$8,700	$700		$15,400	$1,500
End Center Fork Spill	Spill			$8,700	$700		$15,400	$1,500
Hatch Spill	Spill			$8,700	$700		$15,400	$1,500
Block Road Spill	Spill	Provide accurate and accessible measurement of spillage flow rate from the lateral as feedback loop on heading operation, general lateral operation, and District water accounting.	Replace weir box with new. Install sharp crested weir plate and mount custom staff gage calibrated to report spill flow rate based on the depth of water above the weir crest.	$8,700	$700	Install pressure transducer in new stilling well upstream of spill box to measure head on weir. Perform calibration of weir. Install communication hardware and integrate with SCADA system to allow remote monitoring.	$15,400	$1,500
Evans Spill	Spill			$8,700	$700		$15,400	$1,500
End Shepherd Spill	Spill			$8,700	$700		$15,400	$1,500

Table 13. Summary of Drain Water Recovery Improvement Sites.

Site Name	Description of Operational Objective with Improvements	Level 1 Modernization and Enhancement	Capital Cost ($)	Annual Cost ($/yr)	Level 2 Modernization and Enhancement	Capital Cost ($)	Annual Cost ($/yr)
Redwood Recycle Pumps	Re regulate flow in the Green Lateral to provide constant flowrate to downstream deliveries. Excesses in supply are spilled to Hamilton Drain instead of being passed downstream, and deficiencies are met by extracting drain water.	Add measuring device(s) to measure pump(s) discharge and improve manual operation. Construct permanent weir crests on either side of flume walls to maintain water level and spill excesses to Hamilton Drain.	$21,000	$1,150	Add VFD controller to pump station to provide automated upstream water level control. Add communication hardware to site and integrate with SCADA system to provide real-time monitoring of flow rates, water level, and pump status.	$57,330	$3,941
A-Line Recycle Pumps	Re regulate flow in the Branch B Lateral to provide constant flowrate to downstream deliveries. Excesses in supply are spilled to RD833 Drain instead of being passed downstream, and deficiencies are met by extracting drain water.	Add measuring device(s) to measure pump(s) discharge and improve manual operation. Construct permanent weir crests on either side of flume walls to maintain water level and spill excesses to Hamilton Drain.	$14,000	$767	Add VFD controller to pump station to provide automated upstream water level control. Add communication hardware to site and integrate with SCADA system to provide real-time monitoring of flow rates, water level, and pump status.	$44,730	$3,250
Schwind Recycle Pumps	Re regulate flow in the Schwind Lateral to provide constant flowrate to downstream deliveries. Excesses in supply are spilled to the Brooks Drain instead of being passed downstream, and deficiencies are met by extracting drain water.	Add measuring device(s) to measure pump(s) discharge and improve manual operation. Construct permanent weir crests on either side of flume walls to maintain water level and spill excesses to Hamilton Drain.	$21,000	$1,150	Add VFD controller to pump station to provide automated upstream water level control. Add communication hardware to site and integrate with SCADA system to provide real-time monitoring of flow rates, water level, and pump status.	$51,030	$3,596
Ackinson Recycle Pumps	Augment flow in the Belding Lateral to provide constant flowrate to downstream deliveries.	Add measuring device(s) to measure pump(s) discharge and improve manual operation.	$14,000	$767	Install water level sensor in canal downstream of pump discharge. Add communication hardware to site and integrate with SCADA system to provide real-time monitoring of flow rates, water level, and pump status. Provide remote control of pump on or off.	$34,230	$2,675
Owen's Pumps	Augment flow in the Green Lateral to provide constant flowrate to downstream deliveries.	Add measuring device(s) to measure pump(s) discharge and improve manual operation.	$28,000	$1,534	Install water level sensor in canal downstream of pump discharge. Add communication hardware to site and integrate with SCADA system to provide real-time monitoring of flow rates, water level, and pump status. Provide remote control of pump on or off.	$30,030	$2,445
Bilbo Pumps	Provide supplemental flow to Gray Lodge to meet demands. Also improves flexibility on Cassady Lateral by relieving some demand from Gray Lodge.	Add measuring device(s) to measure pump(s) discharge and improve manual operation.	$14,000	$767	Install water level sensor in canal downstream of pump discharge. Add communication hardware to site and integrate with SCADA system to provide real-time monitoring of flow rates, water level, and pump status. Provide remote control of pump on or off.	$44,730	$3,250

Project Costs

Costs for the Boundary Outflow and Primary Spill Measurement Project

Reconnaissance level cost estimates were prepared for both improvement packages described in the preceding sections as a basis for prioritization and funding of site improvements. For the Boundary Flow and Primary Spill Measurement package, the total combined cost (Level 1 and Level 2) of improvement is approximately $376,000, with annual costs of $37,000. Total costs are further summarized in Table 14.

Table 14. Summary of Costs.

	Level 1		Level 2		Combined	
Boundary Flow and Primary Spill Measurement	Capital	Annual	Capital	Annual	Capital	Annual
Boundary Flows Subtotal	$147,900	$15,319	$35,400	$3,600	$183,300	$18,919
Spills Subtotal	$69,600	$5,600	$123,200	$12,000	$192,800	$17,600
Total Cost =	$217,500	$20,919	$158,600	$15,600	$376,100	$36,519

Costs for the Drainwater Recovery Project

The total cost of improving or developing the six drain recovery sites is $379,000 with total estimated annualized costs of $25,000. Total costs are further summarized in Table 15.

Table 15. Summary of Costs.

	Level 1		Level 2		Combined	
Drain Water Recovery	Capital	Annual	Capital	Annual	Capital	Annual
Total Cost (six Sites) =	$112,000	$6,135	$267,120	$18,571	$379,120	$24,706

The aforementioned costs do not include a SCADA base station (which would be required for Phase II) or any mobile operator terminals that would form the backbone of the District SCADA system, or any costs of spare equipment to be kept on hand to repair or replace individual site components due to theft, vandalism, or other failure. These costs are summarized in Table 16. This cost represents a robust SCADA network that would be capable of monitoring the identified measurement and drain recovery sites as well as existing or future sites, such as detailed in the Modernization program. The cost of the office base station may be drastically reduced, or eliminated, if the District is able to 'piggy-back' on to and expand the existing SCADA network owned and operated by the Joint Water Districts and Joint Board.

Table 16. Summary of Costs for SCADA Office Base Station and Spare Parts.

Item	Capital Cost ($)	Annual Cost ($)
SCADA Office Base Station	$138,063	$17,039
Spare Parts	$23,692	$2,913

Potential Benefits

Flow paths targeted under the boundary flow and primary spill measurement and drainwater recovery projects are:

- Operational Spillage

- Tailwater
- Drainage Outflows
- Diversions

Measurement of boundary flows and spills provides operators the tools to reduce operational losses. Reduction in losses may result in decreased required diversions. Available water not diverted remains in storage and could be available to meet local, regional, or statewide objectives.

Reuse of operational spillage and tailwater results in decreased required diversions. Available water not diverted remains in storage and could potentially be available to meet local, regional, or statewide objectives. Because several of the drain water recovery sites are already in use by BWGWD, improvements will increase the functionality of these sites, but not necessarily net additional conserved water.

Through implementation of these projects, it is estimated that approximately 5 to 15 percent[10] of existing boundary outflows during the irrigation season could be conserved, or between approximately 5,000 and 15,000 af per year depending on the level of implementation.

Net Benefit Analysis

The District is currently implementing associated EWMPs at locally cost-effective levels. The cost of additional surface water supplies has been approximately $5 per acre-foot in recent years. The estimated implementation cost per unit of water conserved ranges from approximately $8 to $25 per acre-foot. Currently, the unit cost of conservation exceeds the potential monetary savings. As a result, further implementation of the boundary flow and primary spill measurement and drainwater recovery projects is not locally cost effective at this time; however, BWGWD plans to proceed with improvements and funding and project prioritization allow. In the future, it is anticipated that the costs and estimated benefits of this improvement project will be evaluated as additional information becomes available.

[10] Based in part on percent reductions in spillage for various improvement measured listed in the technical memorandum "Spillage Reduction- Monitoring and Verification" published by the Agricultural Water Management Council, and partly on experience with local conditions and judgment.

3.10.5 Drought Management Plan

Background and Overview

On April 1, 2015 Governor Brown issued Executive Order B-29-15, mandating agricultural water suppliers to include a detailed Drought Management Plan (DMP) describing actions and measures taken to manage water demand during drought. BWGWD has historically experienced very reliable surface water supplies with a full surface water supply of 161,000 acre-feet available in all but four years (1977, 1991, 1992, and 2015) since construction of Lake Oroville and its subsequent 1969 settlement agreement with the State. During years in which curtailment is allowed under the agreement, BWGWD's water supply can be reduced by up to approximately 50 percent, as discussed in greater detail below.

For purposes of this DMP, drought years are generally considered as years of reduced surface water supply due to curtailment. BWGWD's drought management actions and shortage allocation policies have been relatively consistent in the past but are evolving in part as a result of the district's implementation of customer delivery measurement improvements under SBx7-7. Specifically, the implementation of these improvements will allow the district to apportion available surface water supplies across the assessed acreage during periods of future shortage, rather than limiting the allowable planted acres (for rice and other annual crops) or limiting the number of available irrigations (for orchards and pasture).

The District recognizes the need for fair, consistent policies to address periods when customer demands exceed BWGWD available supplies. This DMP describes and expands upon BWGWD's shortage allocation policies, including discussion of a broad range of actions undertaken during drought to manage available water supplies and meet customer demands to the maximum extent possible.

The DMP includes components recommended by DWR in its 2015 AWMP Guidebook (DWR 2015). BWGWD's DMP describes the determination of available water supply, drought responses, and water shortage impacts. The description of water shortage impacts includes a discussion of 2015 supply and demand conditions available at the time of preparation of this DMP. A description of supplies and demands for 2013 and 2014, also required under Executive Order B-29-15, is included in the water balance section of this AWMP (II.3.7).

Determination of Available Water Supply

Despite curtailment being dictated by the 1969 settlement agreement with the State, monitoring of hydrologic conditions to assess available water supply is important to BWGWD's water management under the full range of hydrologic conditions experienced. To inform decisions related to available water supply, BWGWD actively monitors water supply as reported by the Department of Water Resources (DWR) for Lake Oroville. As stipulated in the 1969 agreement BWGWD's water supply depends on the Lake Oroville inflow. BWGWD's surface water supply can be reduced under the following conditions:

- DWR forecasted April to July unimpaired runoff into Lake Oroville is less than 600,000 af[13], or
- Total current year predicted and prior year actual deficiencies in unimpaired runoff (as compared to 2,500,000 af) exceed 400,000 af for one or more successive prior water years with less than 2,500,000 af of runoff.

When a reduction is allowed, the Joint Board allotment of 560,000 af can be reduced by up to 50 percent in any one year, but not by more than 100 percent in any seven consecutive years. Additionally, reductions in any given year cannot exceed the percent reduction experienced for agricultural use by State Water Project (SWP) contractors.

Historically during years of curtailment, DWR has curtailed Joint Board water supplies by the full allowed amount, 50 percent, in each instance. For BWGWD, which is entitled to 29 percent of the Joint District supply, the curtailment year apportionment is 81,200 af.

Additionally, under the 1969 settlement agreement, the Joint Districts receive an additional 35,000 af of surface water supply in a year with 50 percent reduction. This 35,000 af is divided equally among the Joint Districts, providing an additional 8,750 af. As a result, BWGWD's surface water supply in a year with 50 percent reduction is 89,950 af, or approximately 56 percent of the normal year supply of 160,950 af.

To stay up date with current water conditions, BWGWD monitors precipitation and snow forecasts, accumulated precipitation and snow, reservoir runoff, reservoir storage, groundwater levels, and instream flows. These provide valuable information regarding water supply availability for the district's manager and customers prior to and leading up to the final determination of water supply availability under the settlement agreement.

Drought Responses

This section describes actions and activities undertaken by BWGWD to address surface water shortage, including discussion of existing and emerging shortage allocation policies described in Section II.3.9 of this AWMP, coordination and collaboration, supply management and demand management.

<u>Shortage Allocation Policies</u>

During periods of curtailment, the District's Board of Directors determines the course of action to manage available water supplies according to the District's current drought policy. In general, the policy combines measures to reduce irrigation runoff (tailwater) and operational spillage while equitably distributing available surface water supplies and facilitating the conveyance of private groundwater pumping through the distribution system to meet additional irrigation demands. This conjunctive use strategy maximizes the use of available surface water supplies to meet irrigation demands during full-supply years and relies on available groundwater supplies in curtailment years.

[13] The final, official forecast must be made by April 10 of each year.

Historically, BWGWD has rationed available surface water supplies in curtailment years by limiting planted acreage for rice and other annual crops and by reducing the number of irrigations available for orchards and pasture. As a result of implementation of delivery measurement improvements under SBx7-7, it is anticipated that during future curtailments BWGWD will instead apportion available surface water supplies across the assessed acreage. This will allow customers to make more precise planting and irrigation decisions for individual fields to optimize available district surface water and private groundwater supplies.

Coordination and Collaboration

BWGWD coordinates and collaborates extensively with others regarding local and regional water management in all years. These activities intensify during periods of drought in order to minimize adverse drought impacts across a range of stakeholders. Examples of collaboration and coordination activities include the following:

- Coordination with the other Joint Districts, WCWD, and the State with regard to Feather River water supplies and demands
- Reporting of information to the California Department of Water Resources, the United States Bureau of Reclamation, and other governmental entities as necessary
- Ongoing interactions with SWP operations and CVP operations to facilitate CVPIA deliveries to GLWA

Additionally, the District participates in the Butte County Water Commission Technical Advisory Committee on issues regarding overall water management, surface water and groundwater resources, and public education and outreach and is actively implementing the Sustainable Groundwater Management Act of 2014 (SGMA) as a Groundwater Sustainability Agency (GSA).

Supply Management

Extraordinary Operational Measures

In recent years, BWGWD has made substantial improvements to both distribution system infrastructure and operational practices to improve overall system management and increase operational efficiency. During periods of surface water shortage, BWGWD takes additional, extraordinary measures to further increase operational efficiency and conserve available water supplies. Highlights of BWGWD activities in recent years to increase operational efficiency include the following:

- BWGWD has improved water level control, system capacity and flexibility, reduced seepage losses, and improved turnouts and drains as part of the Gray Lodge Wildlife Area Water Supply Project (GLWAWSP).
- BWGWD is implementing a Customer Delivery Measurement Program (CDMP) that will improve overall system management and incorporates tools for operators to support increased operational efficiency.
- In 2015, BWGWD expanded training and communications tools for operational staff to support improved operation of laterals and reduction in spillage. This included installing measurement structures at key lateral headings and water level monitoring sensors at

strategic main canal locations. These sites were integrated into the District's SCADA system to provide operators with additional remote monitoring data in real time.

- In 2015, coordination among operators and with customers was substantially increased. This resulted in a noted reduction in surface outflows through a combination of efforts in recent years and extraordinary drought actions.

Supply Augmentation

BWGWD water supplies have been generally sufficient during years with full surface water supply. Historical contributions of surface water recharge to the underlying groundwater system allow growers within BWGWD to pump groundwater in years of surface water shortage to augment available water supplies. Historically, all groundwater pumping during years of surface water storage has been private. The District does not own or operate any groundwater wells, although it allows growers to optimize the use of available groundwater during drought by making the District's conveyance system available to convey groundwater pumped using private wells. Also, in 2015, the Board of Directors approved the construction of a District groundwater well to augment supply in future years of surface water storage. The conjunctive management of surface water and groundwater supplies over time is a key component of BWGWD's drought management strategy.

BWGWD also operates drainwater recovery pumps at six different locations within the District. These pumps are utilized for drainwater recovery into the distribution system for reuse during normal years and are used more extensively to maximize drainwater recovery in curtailment years, to the extent drainwater is available[14].

<u>Demand Management</u>

BWGWD encourages efficient on-farm water management to control demand on an ongoing basis. During curtailment years, these efforts are enhanced through several extraordinary actions, which may include the following:

- Additional grower education and outreach
- Reduction in allowable planted acreage (rice and other annual crops)
- Reduction in number of irrigations (orchards and pasture)
- Enhanced enforcement of rules and regulations

These actions are summarized in the remainder of this section. As discussed previously, it is anticipated that BWGWD will apportion available surface water over the assessed acreage during future curtailment years as a result of implementation of its CDMP.

Outreach and Incentives

During periods of reduced supply, BWGWD increases outreach efforts to encourage on-farm water conservation and to keep growers informed of hydrologic conditions and any changes to BWGWD policies and practices to manage limited water supplies.

[14] The availability of drainwater for recovery and reuse during curtailment years is diminished due to reduced tailwater and operational spillage within the District and entering the District from upstream users. Additionally, increased groundwater pumping during curtailment years may temporarily lower groundwater levels, leading to increased seepage losses for the drains to the underlying aquifer.

Reduction of Allowable Planted Acreage and Allocation of Available Supplies
Under the reduced surface water supply conditions of 2015, BWGWD allocated available surface water supplies by enforcing reductions in planted acreage for rice and other annual crops grown exclusively using surface water supplies. Prior to the start of the 2015 irrigation season each landowner was required to confirm planted acreage with District staff.

In order to maximize the availability of water supplies during 2015, BWGWD facilitated the conveyance of privately pumped groundwater to additional acreage. For privately pumped groundwater conveyed through the distribution system to additional acreage, the following steps were taken:

- Flow meters were required on groundwater pumps
- Required pumping amounts were calculated based on the planted acreage relying on comingled groundwater, estimated per-acre crop duties, and carriage loss
- Pumping was monitored over the course of the 2015 irrigation season to ensure the required pumping amount was achieved

Enhanced Enforcement of Rules and Regulations
BWGWD's Irrigation Rules (AWMP Attachment A) require that all water be applied efficiently and used in a reasonable and beneficial manner. During an irrigation delivery, the irrigator is responsible for the water at all times after it leaves the BWGWD distribution system. Irrigators who waste water intentionally or as a result of carelessness, improper field preparation, or neglected facility maintenance may be refused BWGWD water until the cause of the condition is remedied.

During periods of water supply shortage, BWGWD increases enforcement of rules related to the unauthorized use of water and tailwater runoff. The District employs a no spill policy for tailwater, which includes notification and disciplinary steps.

Water Shortage Impacts

Supplier Revenues and Expenses
The District's water charges have historically been determined using a fixed (per-acre) rate dependent on the crop grown, time of year (summer vs. winter), and water source (gravity delivery vs. drain delivery). As a result, revenues have been greatly reduced in curtailment years due to large reductions in planted acres. In addition to reduced water charges to irrigation customers, revenues decrease as a result of decreased water sales through out of district agreements and water transfers. These reductions in revenue were mitigated in part in 2015 by the District's new water rate structure, which allows the District to increase rates in curtailment years to recover approximately one half of the revenue that would otherwise be lost.

In addition to reduced revenues during curtailment years, operating costs increase substantially due to several factors. These increased expenditures are mitigated somewhat by a combination of measures, including the following:

- Temporarily reducing expenditures for capital improvements and maintenance to allow for more emphasis on system operations and demand management
- Drawing on available reserves to help cover costs

Increased expenditures include the following:

- Increased staff time providing direct irrigation customer service and outreach to the public
- Increased drainwater recovery pumping costs
- Increased weed control costs due to low canal flows
- Increased reliance on outside legal and technical experts to address River operations and water rights issues

Impacts on Water Supplies

To illustrate actions by BWGWD and its customers to manage available water supplies during drought, water supplies for 2015, to the extent available, are summarized and compared to prior years. **All estimates for 2015 are preliminary and subject to revision.** The years 1999 through 2014 represent years where the full surface water supply was available for diversion by BWGWD. The year 2015 represents are year in which BWGWD surface water supply was curtailed by 50 percent.

Average monthly Feather River diversions for BWGWD from 1999 to 2014 are shown in Figure 1, along with preliminary estimates of diversions for April through October 2015. Total average diversions between April and October were 173,000 af between 1999 and 2014 and 97,000 af in 2015. Diversions during 2015 are greater than 50% of BWGWD's 161,000 af allotment in part due to CVPIA water wheeled to GLWA that does not count against the District's allotment.

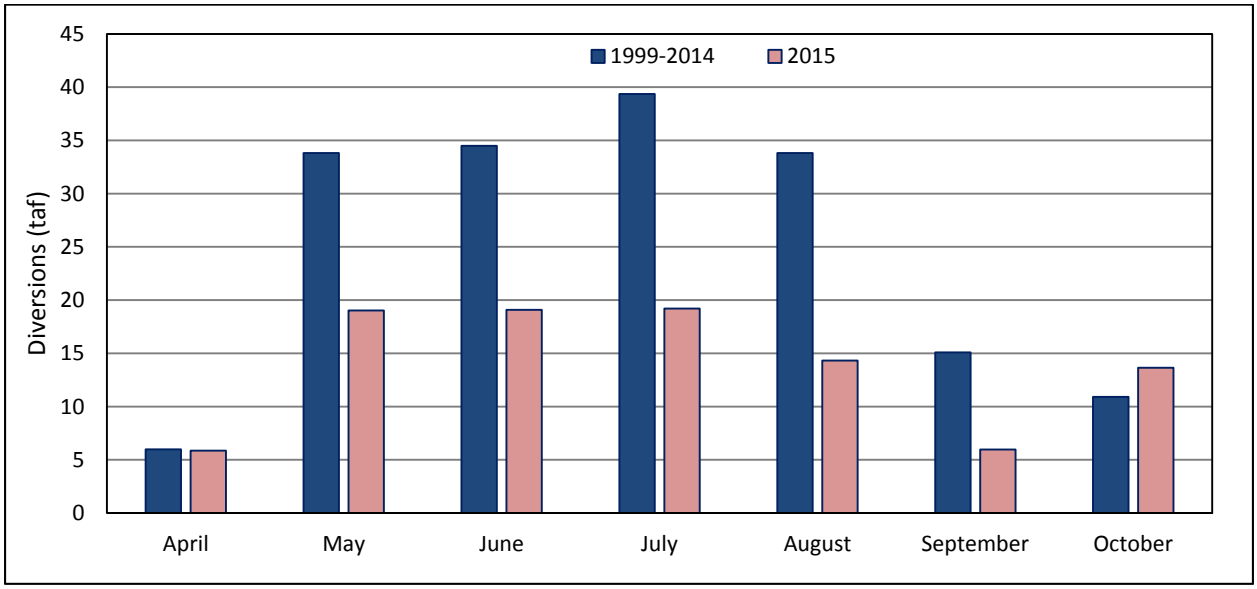

Figure 1. BWGWD April to October Diversions, 1999-2014 Average and 2015 Preliminary.

Average monthly estimates of groundwater pumping for BWGWD from 1999 to 2014 are shown in Figure 2, along with preliminary estimates of groundwater pumping for April through October

2015. The increase in groundwater pumping in 2015 in response to curtailment was estimated as follows:

- Flowmeter records for comingled groundwater pumped into the BWGWD distribution system (20,800 af)
- 2,000 additional acres of lands irrigated with groundwater that was not comingled with the distribution system at an average application of 6 af/ac (12,000 af)

Total average estimated groundwater pumping volumes between April and October were 4,700 af between 1999 and 2014. The preliminary total April to October pumping volume for 2015 is 37,500 af, which includes 4,700 of baseline pumping, 20,800 af of comingled groundwater pumping, and 12,000 af of no-comingled groundwater pumping. Baseline pumping primarily represents estimated groundwater pumping by GLWA within the BWGWD boundary.

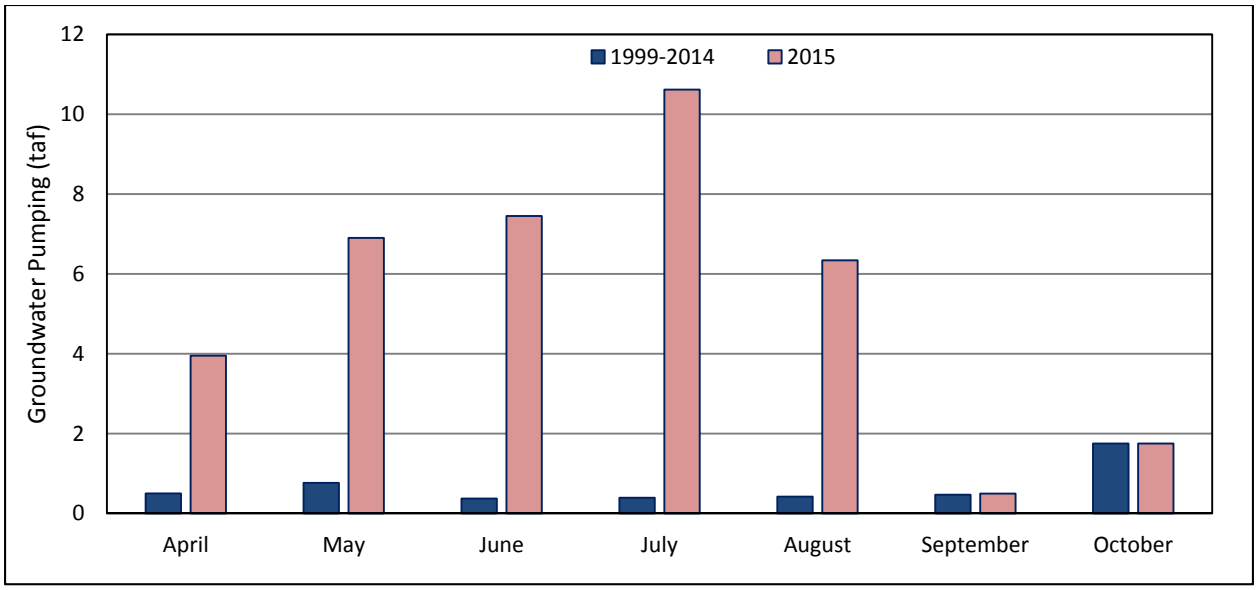

Figure 2. BWGWD April to October Private Groundwater Pumping, 1999-2014 Average and 2015 Preliminary.

Total diversions and private groundwater pumping, which represent the primary sources of irrigation supply in BWGWD are shown in Figure 3. Total average diversions and groundwater pumping between April and October were 178,000 af between 1999 and 2014 and 135,000 af in 2015.

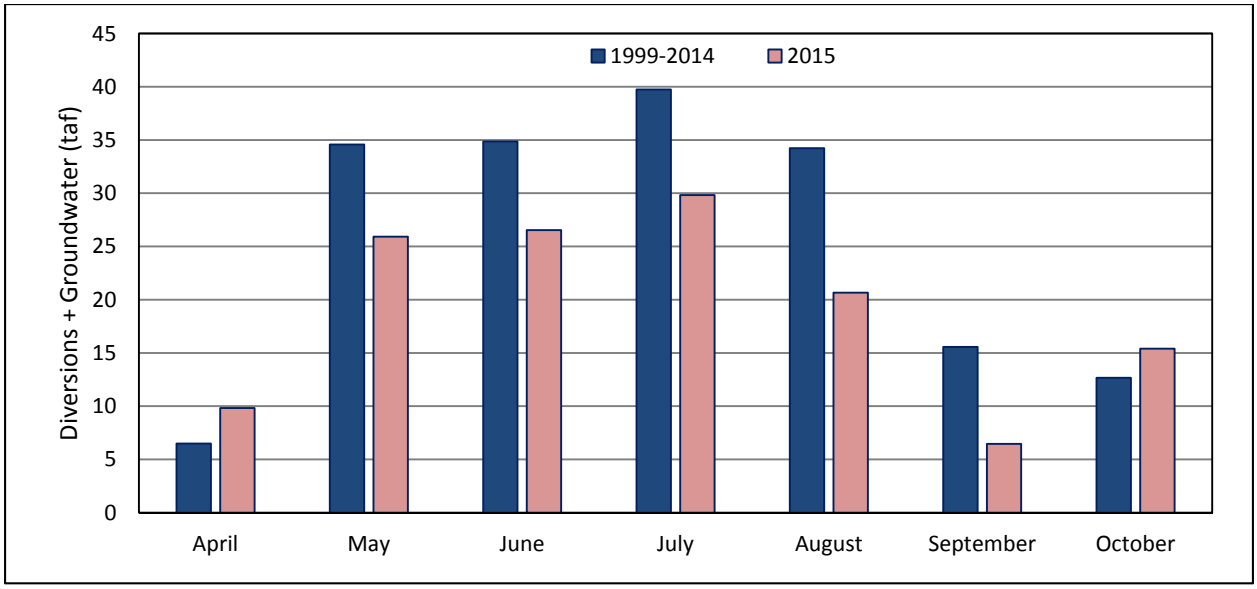

Figure 3. BWGWD April to October Diversions and Private Groundwater Pumping, 1999-2014 Average and 2015 Preliminary.

Other water supplies available to BWGWD and its customers include water reuse through drainwater recapture. Estimates of drainwater recapture have not been prepared for 2015 at the time of preparation of this AWMP.

Demand Impacts

To illustrate impacts on demand caused by drought, demands for 2015, to the extent available, are summarized and compared to prior years. **All estimates for 2015 are preliminary and subject to revision.** The years 1999 through 2014 represent years where the full surface water supply was available for diversion by BWGWD and demands were fully met. The year 2015 represents are year in which BWGWD surface water supply was curtailed by 50 percent and demands were reduced due to the corresponding reduction in surface water supply, except as offset by increased groundwater pumping to maintain supply reliability and increased operational and on-farm efficiency to stretch available supplies.

Average monthly estimated deliveries for BWGWD from 1999 to 2014 are shown in Figure 4, along with preliminary estimates of deliveries for April through October 2015. Total average deliveries between April and October were 155,000 af between 1999 and 2014 and 98,000 af in 2015. Deliveries during 2015 are approximately equal to diversions, suggesting an increase in operational efficiency through reduction of operational spillage and increased District drainwater reuse. Deliveries represent surface water only and do not include comingled private groundwater pumping that was conveyed through the BWGWD distribution system.

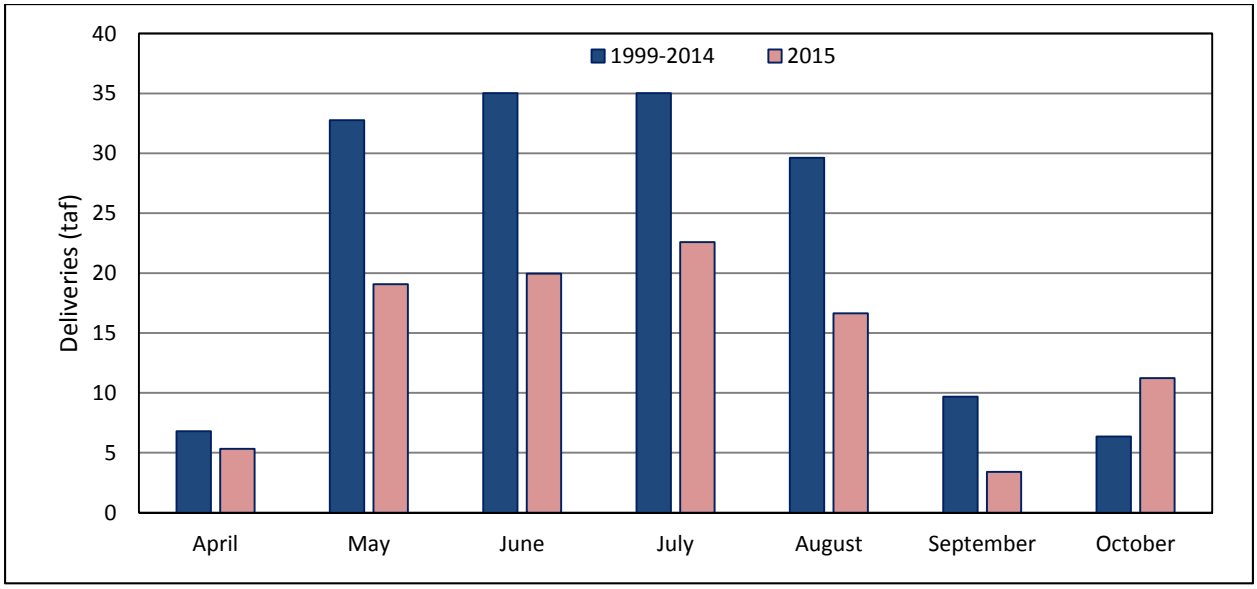

Figure 4. BWGWD April to October Deliveries, 1999-2014 Average and 2015 Preliminary.

References

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